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THE NUTRIENT ASSIMILATION CAPACITY OF THE LITTLE WEKIVA RIVER

FINAL REPORT

Submitted to:

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (L)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
Celsius degrees (C)	1.8(C) + 32	Fahrenheit degrees

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EXECUTIVE SUMMARY

A three year research project was initiated in 1984 to determine the nutrient assimilation capacity of the Little Wekiva River. The project was designed to assess the effects of discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant on stream hydrology, water quality, and biology. The primary objective was to determine if there was a relationship between stream nutrient concentrations and the abundance of aquatic macrophytes, especially paragrass (*Brachiaria mutica*, formerly *Panicum purpurescens*). Relationships between nutrient concentrations and the abundance of other aquatic plants and animals were also examined to determine if nutrient enrichment was causing an imbalance in the stream's populations of aquatic flora and fauna. Field studies were also conducted on 16 additional Florida streams including unpolluted spring-fed streams and streams receiving discharges of treated domestic wastewater to determine how the biota of Florida streams respond to nutrient enrichment.

The Little Wekiva River had an average discharge of 3.8 m^3/s between January 1985 and December 1986. Discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant constituted about 13% of the total streamflow. The Altamonte Springs Regional Wastewater Treatment Plant and the

Hi-Acres Citrus plant each contributed about 6% of the total flow. The Weathersfield Sewage Treatment Plant contributed < 1% of the water leaving the Little Wekiva River. Water from Sanlando Spring, Palm Spring, and Starbuck Spring constituted 36% of the total discharge. In the upper Little Wekiva River (above State Road 434), discharges from the Altamonte Springs Regional Wastewater Treatment Plant (23%), the Weathersfield Sewage Treatment Plant (1%), and the Hi-Acres Citrus processing plant (24%) constituted 48% of the average streamflow. During periods of low rainfall, discharges from the major anthropogenic point-sources constituted over 20% of the total streamflow leaving the Little Wekiva River and virtually all the streamflow in the upper Little Wekiva River.

Discharges of water rich in minerals and nutrients from the Altamonte Springs Regional Wastewater Treatment Plant and the Weathersfield Sewage Treatment Plant significantly increased the total salinity and nutrient levels of the upper Little Wekiva River. Downstream of the wastewater treatment plants, the total salinity of the stream and nutrient levels were reduced by discharges from the Hi-Acres Citrus processing plant, Sanlando Spring, Palm Spring, and Starbuck Spring, but nutrient concentrations in the stream remained elevated. Total phosphorus concentrations averaged 0.36 mg/L and total nitrogen concentrations averaged 1.1 mg/L in the lower Little Wekiva River. Discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant contributed approximately

40% of the total phosphorus and total nitrogen exported from the Little Wekiva River to the Wekiva River. The Hi-Acres Citrus processing plant, however, discharged waters with low nutrient concentrations that diluted in-stream nutrient concentrations in the Little Wekiva River. These discharges ceased in 1986. This represents a significant loss of high quality dilution water.

The abundances of suspended algae in the Little Wekiva River and the other small Florida streams sampled during the study were not controlled by nutrient enrichment. Physical factors such as current velocity, hydrographic instability, discharge, and light limitation were the primary factors limiting algal abundance. Algal assay studies performed with waters taken from the Little Wekiva River and the survey streams demonstrated that significantly higher chlorophyll a concentrations could be obtained if algal populations were given sufficient time (> 2 days) to develop. Even the unpolluted waters from Sanlando Spring, Palm Spring, and Starbuck Spring had the capacity to develop chlorophyll a concentrations > 20 mg/m^3. The "age" of the water, therefore, was the most important determinant of suspended algal populations in the small study streams, but nutrients could be regulating algal abundance in slow-flowing streams or large rivers like the St. Johns River.

Nuisance growths of aquatic macrophytes in the Little Wekiva River were not linked to nutrient enrichment. Equivalent or higher standing crops of aquatic macrophytes were measured in the unpolluted spring-fed streams that had average total phosphorus concentrations $\leq$ 0.04 mg/L and average total nitrogen concentrations $\leq$ 0.40 mg/L. Sanlando Spring, Palm Spring, and Starbuck Spring discharged waters having an average total phosphorus concentration > 0.1 mg/L and an average total nitrogen concentration > 0.4 mg/L. Aerial photographs taken in 1940 showed that the Little Wekiva River was blocked by aquatic macrophytes (probably water hyacinths) even before significant amounts of nutrient-rich wastewater were discharged to the stream. Aquatic macrophytes in the Little Wekiva River and most of the other study streams also contained < 2% of the annual nutrient discharge.

The abundances of aquatic macrophytes in the Little Wekiva River and the other small Florida streams sampled were controlled primarily by physical factors such as substrate quality, current velocity, and shading. Shading by streambank vegetation was the dominant factor controlling the location and abundance of aquatic macrophytes. Statistical analyses indicated that the average and maximum standing crop of aquatic macrophytes in the Florida streams were related to forest canopy coverage and the relationships were described by the equations

$$\log (SC_{avg}) = 1.06 - 0.026\ (\%C) \qquad R^2 = 0.93$$

$$\log (SC_{max}) = 1.54 - 0.014\ (\%C) \qquad R^2 = 0.94$$

where SC_{ave} and SC_{max} are the average and maximum standing crop of aquatic macrophytes (kg fresh weight/m^2), respectively, and %C is the percent canopy coverage by streambank vegetation.

Although nutrient enrichment was not the primary factor controlling the abundances of aquatic plants in the Little Wekiva River and the other small Florida streams, nutrient enrichment and/or the introduction of organic matter seemed to be stimulating stream productivity. Streams receiving nutrient-rich discharges from wastewater treatment plants supported more total and harvestable fish per hectare than the unpolluted spring-fed streams. Harvestable fish stocks and standing crops for the streams receiving treated domestic wastewaters averaged 230 fish/ha and 46 kg/ha, respectively. Streams receiving no treated wastewater averaged 80 harvestable fish/ha and 18 kg of harvestable fish/ha. Three of the unpolluted spring-fed streams (Alexander Springs, Ichetucknee Springs, and Wacissa River) had standing crops of harvestable fish that averaged < 11 kg/ha. Three of the streams (Alligator Creek, Little Econlockhatchee River, and Pottsburg Creek) that received significant inputs of treated wastewater had standing crops of harvestable fish that averaged > 65 kg/ha. The standing crops of harvestable fish were also significantly ($P \leq 0.10$) correlated to stream total phosphorus ($r = 0.55$) and total nitrogen ($r = 0.45$) concentrations.

Erosion of the streambank in the upper Little Wekiva River was severe. This erosion caused the downstream movement of large amounts of sand. The sand filled in many formerly deep areas and assisted the spread of rooted emergent plants by creating many shallow moist sand bars. Beds of submerged aquatic macrophytes were scoured from the streambed or buried by the moving sand. Although the downstream movement of sand is part of a natural geomorphological cycle, much of the increased erosion can be attributed to the removal of streambank vegetation by various human activities.

Nutrient removal by the elimination of nutrient-rich discharges from anthropogenic sources such as the Altamonte Springs Regional Wastewater Treatment Plant cannot be used as an indirect method for the control of aquatic macrophytes in Florida's nutrient-rich streams. Relationships between light availability and the distribution and abundance of aquatic macrophytes suggest that the control of aquatic weed problems in many of Florida's small, shallow, nutrient-rich streams can be accomplished in part by the maintenance of the forest canopy cover. Increased shading will reduce the extreme and rapid development of aquatic macrophytes and prevent the growth of aquatic plants if the forest canopy is sufficiently dense. In large streams or sections of small streams where the forest canopy can not provide sufficient shade, aquatic plant management programs will be needed to prevent aquatic weed problems. The expansion of rooted emergent vegetation such as paragrass in streams is encouraged by erosion which fills in stream channels and reduces the abundance of native submerged aquatic macrophytes. Protection and re-establishment of streambank vegetation is, therefore, recommended as a good ecologically based alternative for the control of aquatic macrophytes and streambank erosion in small streams like the Little Wekiva River, but alternative solutions for erosion control such channelization and bank stabilization will be needed in areas where the establishment of sufficient streambank vegetation is constrained.

Discharges of treated municipal wastewater, given their current levels of treatment and discharge, do not appear to be adversely affecting suspended algal or fish populations in small Florida streams. The development of large algal populations should not be expected in most small streams unless the current velocity is reduced sufficiently to increase the length of time the water is in the streams. Algal populations, however, have the potential to develop downstream in lakes, coastal estuaries, or slow-flowing water bodies like the St. Johns River. Algal assay studies definitively demonstrate that waters from streams receiving discharges of treated domestic wastewater have the potential to develop large (> 20 mg/m^3 of chlorophyll a) populations of suspended algae, but the same is also true of waters from unpolluted springs, spring-fed streams, and natural drainage streams that drain phosphatic regions. The cumulative effects of nutrient-rich discharges on algal and fish populations in the downstream water bodies, however, are poorly known. It is possible that the elimination of anthropogenic nutrient discharges to the lower St. Johns River will not eliminate algal blooms and fish kills. It is also possible that the nutrients are helping support the major sport and commercial fisheries that currently exist in the lower St. Johns River. Additional studies are needed to determine how nutrients and allochthonous organic matter regulate fish production in Florida's streams. A major study of the entire St. Johns River system is recommended to determine if the cumulative effects of anthropogenic nutrient discharges are responsible for algal blooms and fish kills observed in the lower St. Johns River or whether the blooms and fish kills are the result of physical factors interacting with nutrient-rich waters discharged from springs and other streams.

INTRODUCTION

Are discharges of nutrients from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant causing a proliferation of aquatic weeds in the Little Wekiva River? The United States Environmental Protection Agency (1981), after conducting a community metabolism study on the Little Wekiva River in November 1981, concluded that excessive growths of aquatic plants did not seem to be related to nutrient enrichment; the growths of aquatic plants appeared to be controlled primarily by the effects of substrate quality, stream velocity, and shading. The Florida Department of Environmental Regulation subsequently conducted a new wasteload allocation study for the Little Wekiva River and concluded that there was conflicting evidence regarding the relationship between point-source nutrient loads and the proliferation of aquatic weeds in the stream (McClelland 1982). The Department of Environmental Regulation, however, could establish no technically defensible relationship between the point-source nutrient discharges and the growth of aquatic weeds. It was, therefore, concluded that the available data neither supported nor denied a requirement for nutrient removal (McClelland 1982).

We, therefore, initiated in 1984 a three year research project to determine the nutrient assimilation capacity of the Little Wekiva River. The project was designed to assess the effects of discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant on stream hydrology, water quality, and biology. Our primary objective was to determine if there was a relationship between stream nutrient concentrations and the abundance of aquatic macrophytes, especially paragrass (Brachiaria mutica, formerly Panicum purpurescens). We also examined relationships between nutrient concentrations and the abundance of other aquatic plants and animals to determine if nutrient enrichment was causing an imbalance in the stream's populations of aquatic flora and fauna.

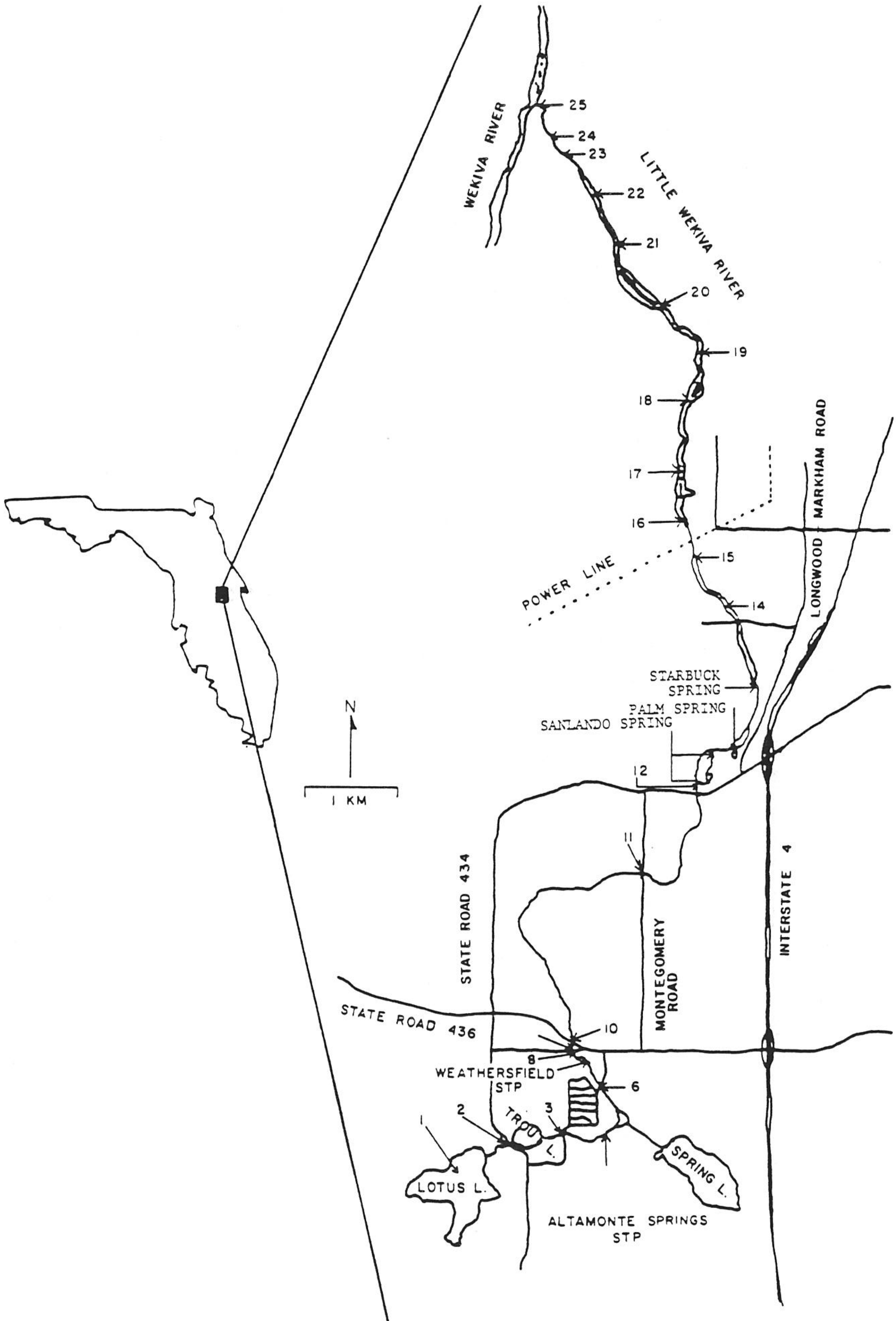
We present evidence in this report that the anthropogenic discharges are significantly influencing stream hydrology and water quality, but that the abundance (coverage and standing crops) of aquatic plants in the Little Wekiva River is not related to nutrient enrichment. Physical factors, such as the hydraulic residence time of the water and shading by riparian vegetation, are the primary determinants of plant abundance in the river. Nutrient control programs, therefore, will not prevent or reduce aquatic weed problems in the Little Wekiva River. We also demonstrate that nutrient enrichment is not adversely affecting the fishes of the Little Wekiva River and may actually be enhancing sport fish abundance by increasing overall stream productivity. The cumulative effects of nutrient discharges on downstream receiving water bodies such as the St. Johns River, however, remain unknown and further investigations of the St. Johns River are recommended.

METHODS

Study Sites

An intensive study of the Little Wekiva River (Seminole County, Florida) was conducted between October 1984 and December 1985. We established 29 sampling stations along the length of the Little Wekiva River between Lotus Lake and the Wekiva River to measure nutrient inputs from both point and non-point sources and to measure changes in stream water quality (Figure 1; Table 1). Although the headwaters of the Little Wekiva River are located further south at Lawne Lake in Orange County, we designated Lotus Lake as the source of the stream for the purposes of this study. Sampling stations were established upstream (Station 2; Figure 2) and downstream (Station 3; Figure 3) of Trout Lake to determine if this remnant lake was altering the stream's water quality. In the upper portion of the stream (above Springs Landing Boulevard), sampling stations were also established at the most obvious point-source discharges into the stream, which included the Altamonte Springs Regional Wastewater Treatment Plant (Station 4; Figure 4), the Weathersfield Sewage Treatment Plant (Station 7; Figure 5), the Hi-Acres Citrus processing plant (Station 9; Figure 6), Spring Lake (Station 5; insignificant flow during this study), Sanlando Spring (Stations 13.1, 13.2, 13.3; Figure 7), Palm Spring (Station 13.4; Figure 8), and Starbuck Spring (Station 13.5; Figure 9). A survey of the upper reaches of the Little Wekiva River revealed numerous

Figure 1. Map of Little Wekiva River in Seminole County, Florida with sampling stations labeled.



WEKIVA RIVER
LITTLE WEKIVA RIVER
25
24
23
22
21
20
19
18
17
16
15
14
POWER LINE
LONGWOOD - MARKHAM ROAD
STARBUCK SPRING
PALM SPRING
SANLANDO SPRING
12
11
N
1 KM
STATE ROAD 434
INTERSTATE 4
MONTEGOMERY ROAD
STATE ROAD 436
10
8
WEATHERSFIELD STP
6
3
2
1
TROUT L.
LOTUS L.
SPRING L.
ALTAMONTE SPRINGS STP

Table 1. Location and description of sampling stations on the Little Wekiva River, Florida.

Station	Distance Downstream (kilometers)	Description
1	0	Lotus Lake
2	0.62	Bridge at Forest City Road; above Trout Lake
3	1.27	Bridge at Northwestern Avenue; below Trout Lake; staff gauge established
4	1.52	Discharge pipe from Altamonte Springs Regional Wastewater Treatment Plant
5	1.81	Discharge from Spring Lake
6	1.96	Bridge at Northwestern Avenue; staff gauge established
7	2.31	Discharge weir at the Weathersfield Sewage Treatment Plant
8	2.45	Bridge at Orange Avenue; staff gauge established
9	2.45	Discharge pipe from Hi-Acres Citrus Processing Plant
10	2.55	Bridge at State Road 436
11	6.24	Bridge at Montgomery Road
12	7.70	3 meters upstream of first discharge from Sanlando Spring
13.1	7.70	Weir of first discharge point for Sanlando Spring
13.2	7.90	Auxiliary discharge for Sanlando Spring
13.3	8.20	Weir at second discharge stream from Sanlando Spring

Table 1 (Cont.).

Station	Distance Downstream (kilometers)	Description
13.4	8.35	Weir at discharge from Palm Spring
13.5	9.22	Weir at Starbuck Spring
14	9.99	100 m below Springs Landing Bridge; start of major paragrass blockage
15	10.76	End of first major area of aquatic plant growth and beginning of closed forest canopy
16	11.28	End of closed forest canopy; start of mixed open and closed canopy cover
17	11.90	10 m below island at home of Colonel Russ Fisher; continuous stage recorder and rain gauge established
18	12.71	End of open canopy habitat; beginning of mixed closed and open habitat
19	13.32	Start of closed forest canopy
20	14.09	Middle of closed canopy habitat
21	15.01	End of closed canopy habitat and start of last section of major aquatic plant growth
22	15.59	Middle of last section of aquatic plant growth
23	16.21	Start of closed forest canopy
24	16.36	Sabol Point Landing
25	16.94	0.6 km above junction with Wekiva River; continuous stage recorder established

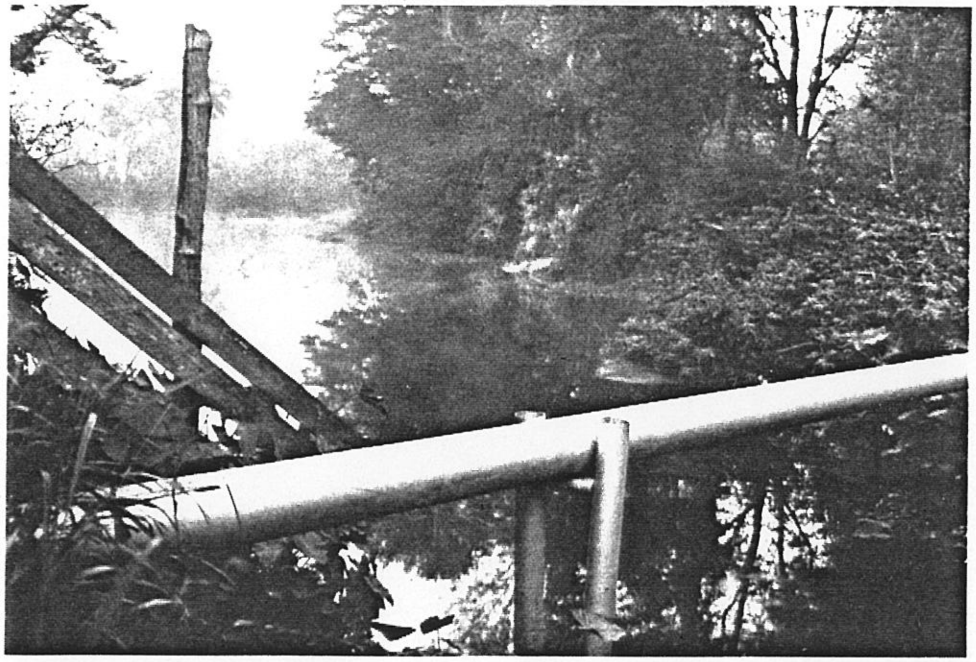


Figure 2. Station number 2 located on the Little Wekiva River.

Figure 3. Station number 3 located on the Little Wekiva River.

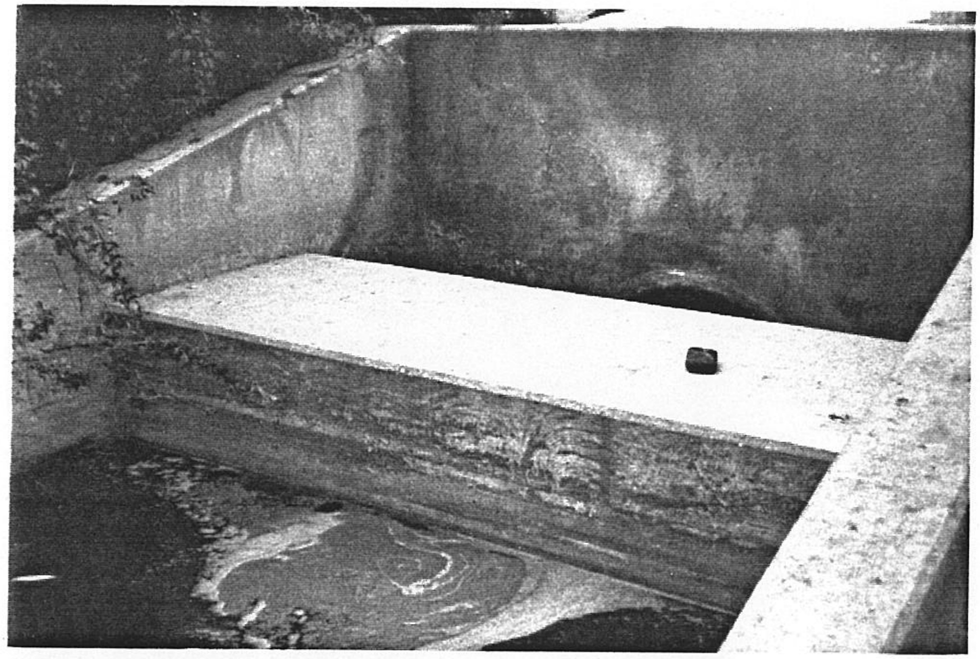


Figure 4. Altamonte Springs Regional Wastewater Treatment Plant (station number 4) located on the Little Wekiva River.

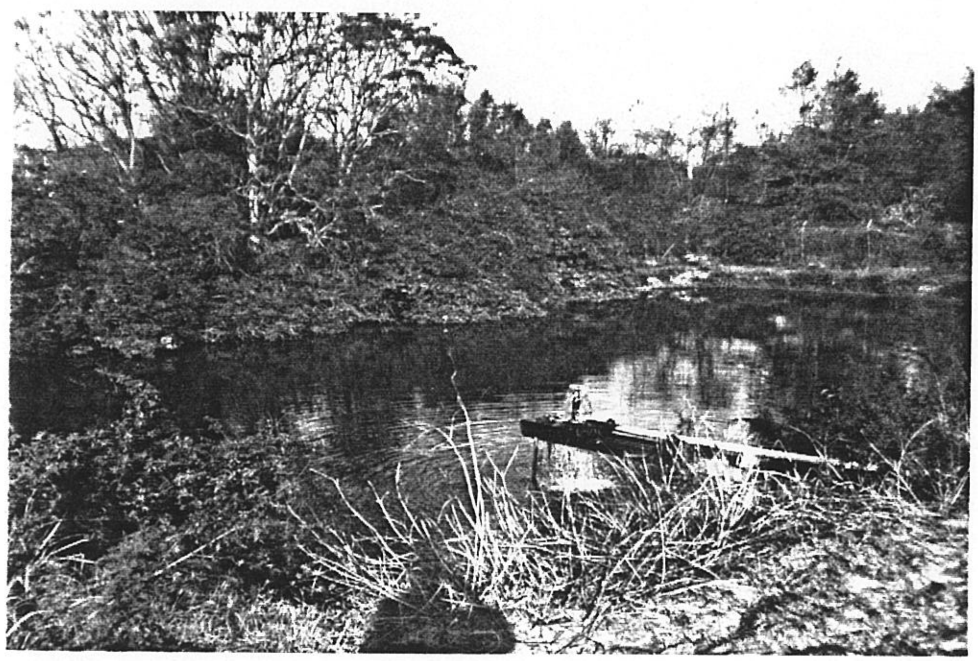


Figure 5. Weathersfield Sewage Treatment Plant (station number 7) located on the Little Wekiva River.

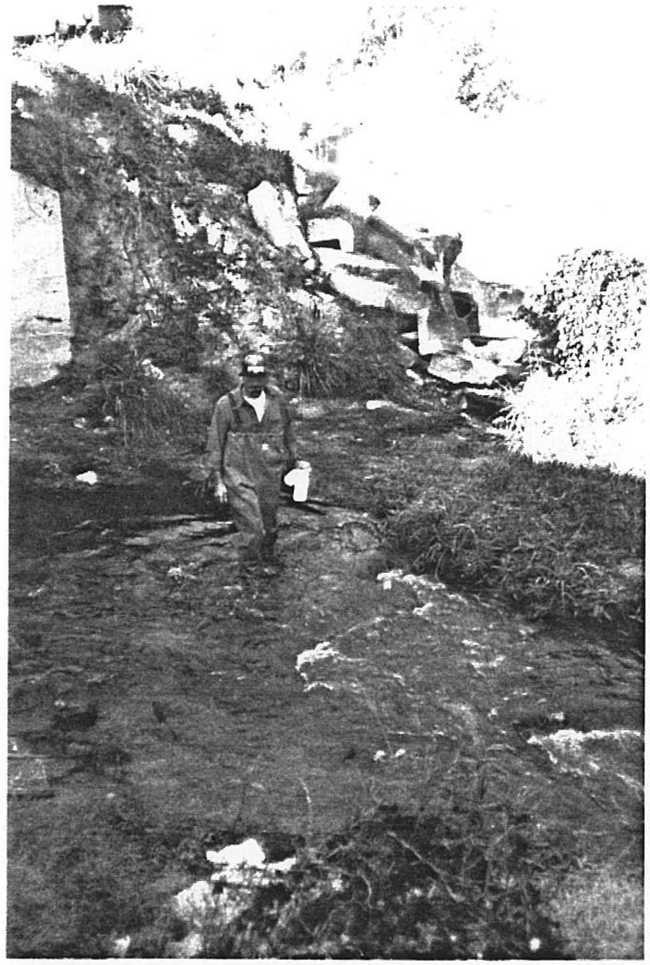


Figure 6. High Acres Citrus Processing Plant (station number 9) and station 8 located on the Little Wekiva River.

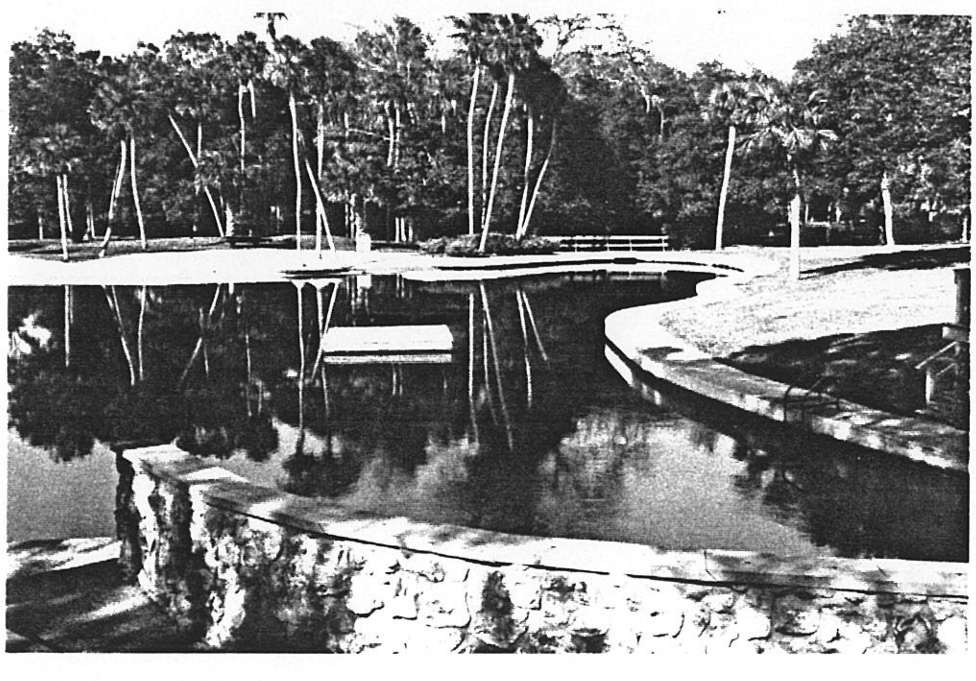


Figure 7. Sanlando Springs (stations number 13.1, 13.2, and 13.3) located on the Little Wekiva River.

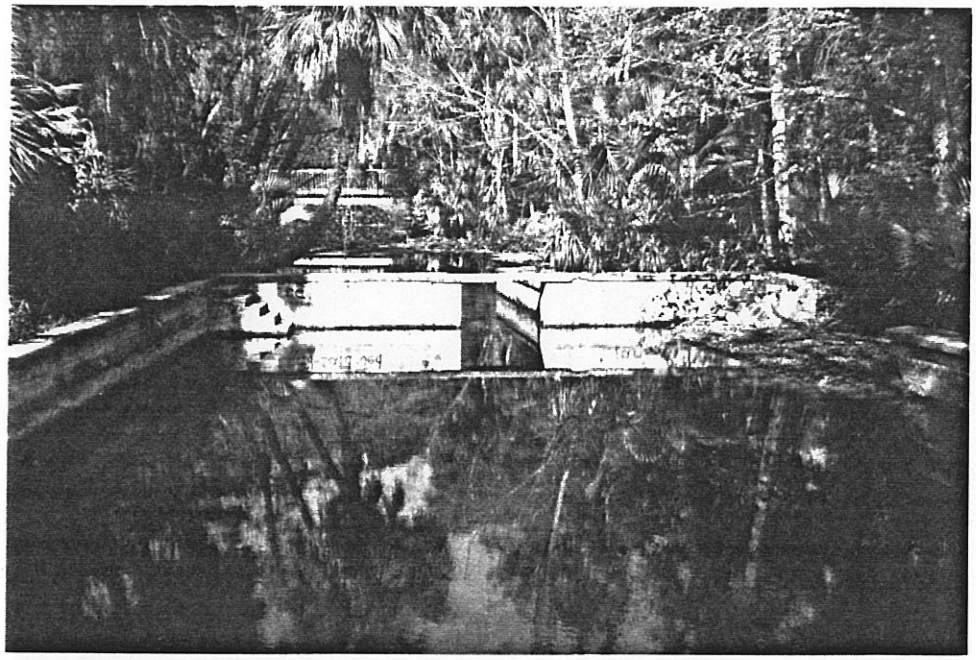


Figure 8. Palm Springs (station number 13.4) located on the Little Wekiva River.

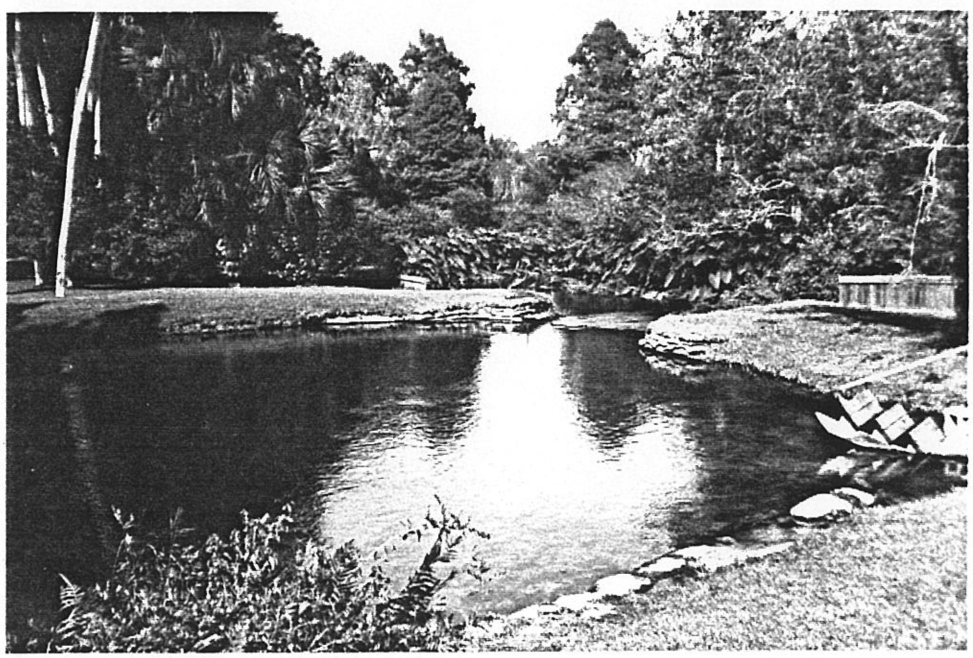


Figure 9. Starbuck Spring (station number 13.5) located on the Little Wekiva River.

discharge pipes and stormwater drains along the initial 10 km of the stream. Because it was not practical to sample all of these discharges, additional sampling stations (Stations 6, 8, 10, 11, and 12; Figures 6, 10, 11, and 12) were established along the stream to determine how these point and non-point source discharges might be influencing stream water quality and flow. Below Starbuck Spring, the Little Wekiva River widened significantly and there were basically two distinct habitat types: open forest canopy where aquatic plants grew in abundance and closed forest canopy where aquatic plant abundance was limited. In the lower Little Wekiva River, sampling stations (Stations 14-25; Figures 13-22) were established at the beginning, middle, and end of the major habitats to determine if aquatic plants were altering water quality in the lower reaches of the stream.

Eight additional streams were selected for study in May 1985 to provide a comparison between streams with low and high nutrient concentrations (Table 2). Alexander Springs (Figure 23), Ichetucknee River (Figure 24), Rock Springs Run (Figure 25), and Wacissa River (Figure 26) were selected for study because the streams were spring-fed like the Little Wekiva River but had no major discharges of treated effluent into them. Alligator Creek (Figure 27) and the Little Econlockhatchee River (Figure 28) were selected because these streams, like the Little Wekiva River, received treated domestic wastewater. The Alafia River (Figure 29) was chosen for study because it drains a major phosphate district and has stream total phosphorus concentrations in excess

Figure 10. Station number 6 located on the Little Wekiva River.

Figure 11. Station number 10 located on the Little Wekiva River.

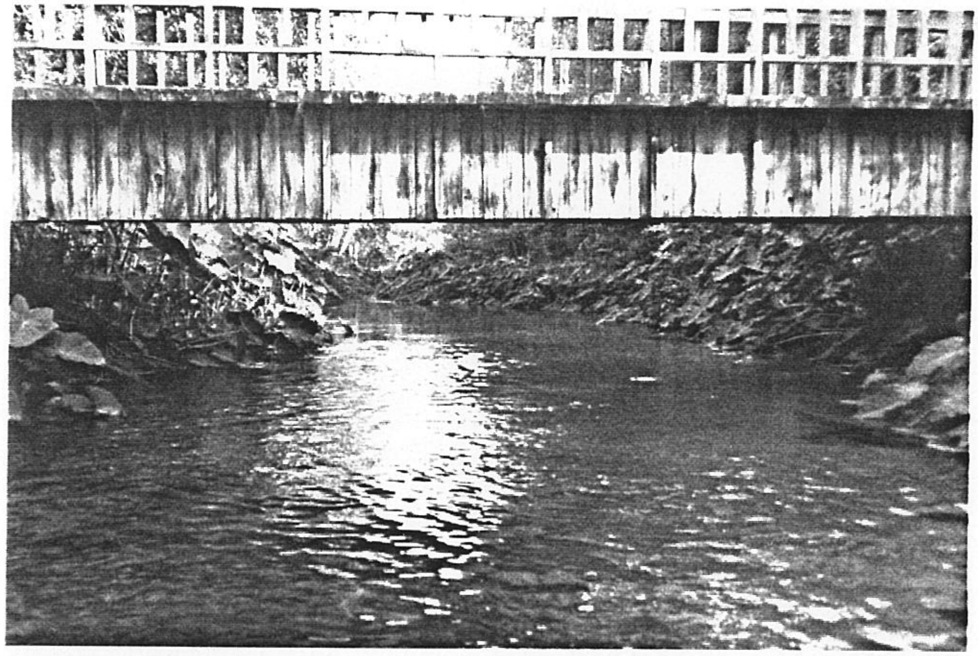


Figure 12. Station number 12 located on the Little Wekiva River.

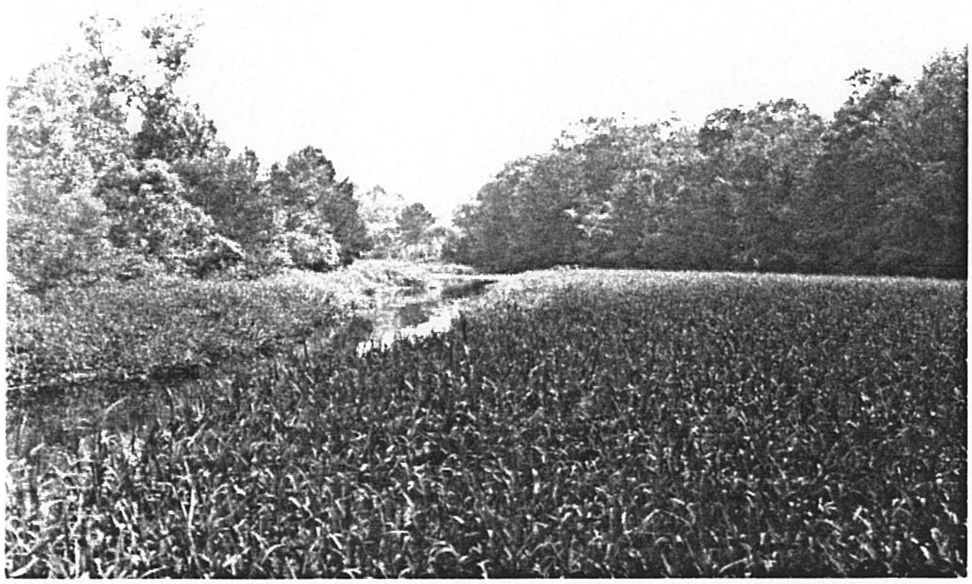


Figure 13. Station 14 located on the Little Wekiva River.

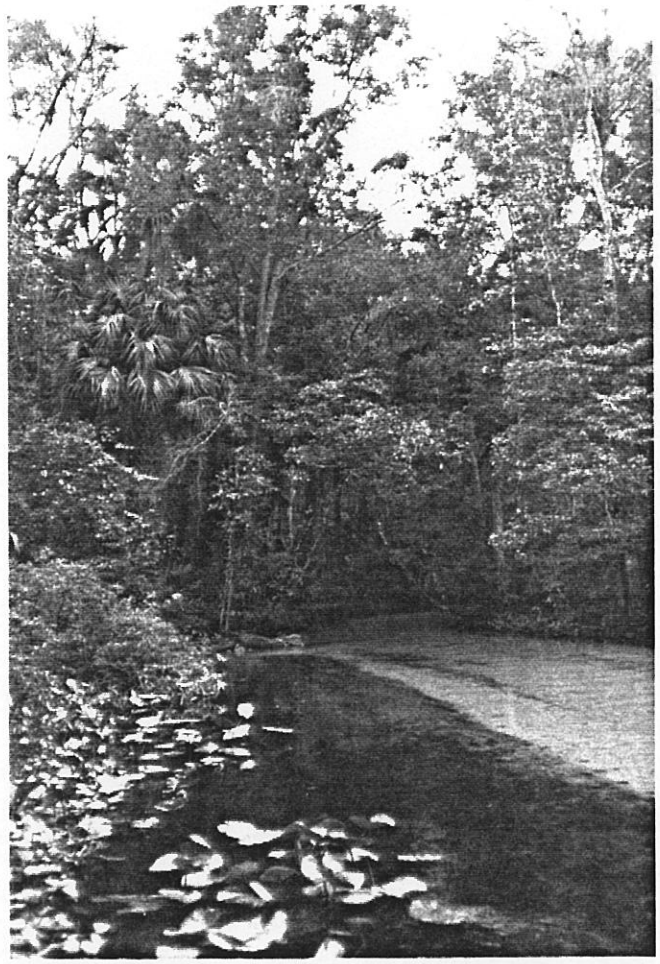


Figure 14. Station number 15 located on the Little Wekiva River.

Figure 15. Station number 16 located on the Little Wekiva River.

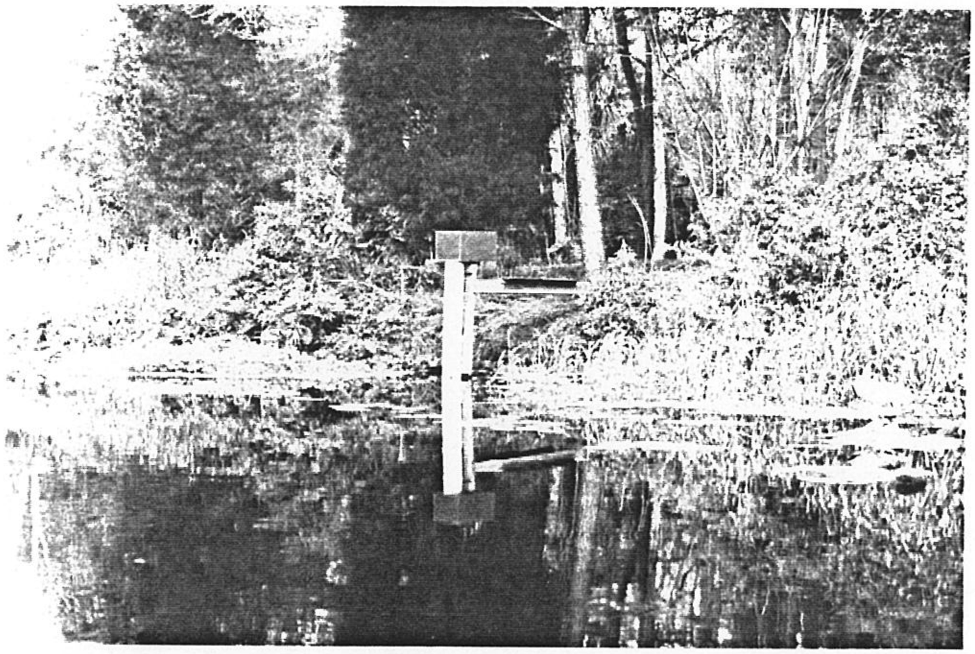


Figure 16. Station number 17 located on the Little Wekiva River.

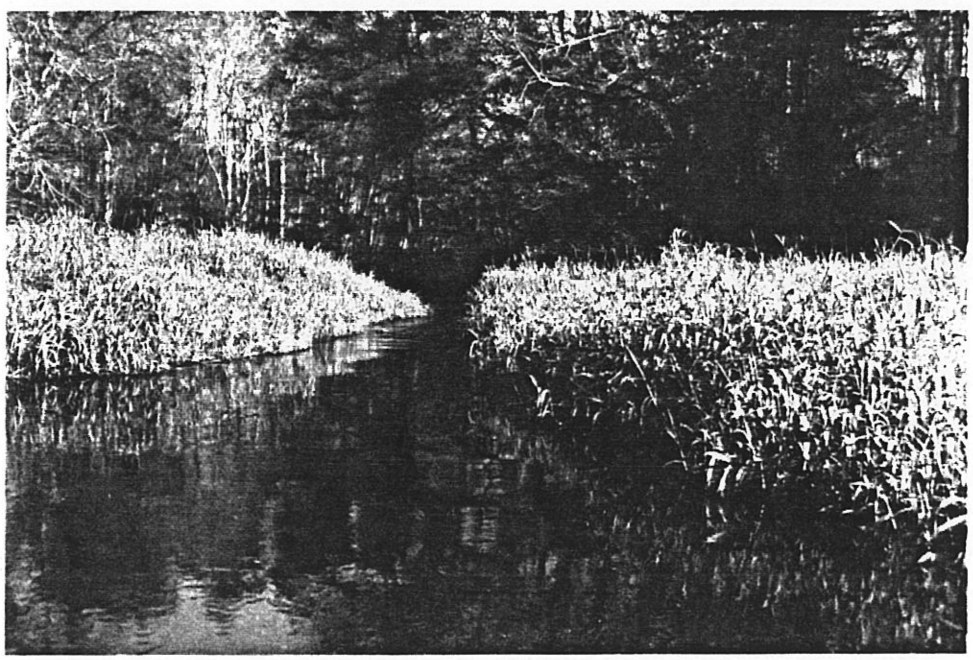


Figure 17. Station number 18 and 19 located on the Little Wekiva River.

Figure 18. Station number 20 located on the Little Wekiva River.

Figure 19. Station number 21 located on the Little Wekiva River.

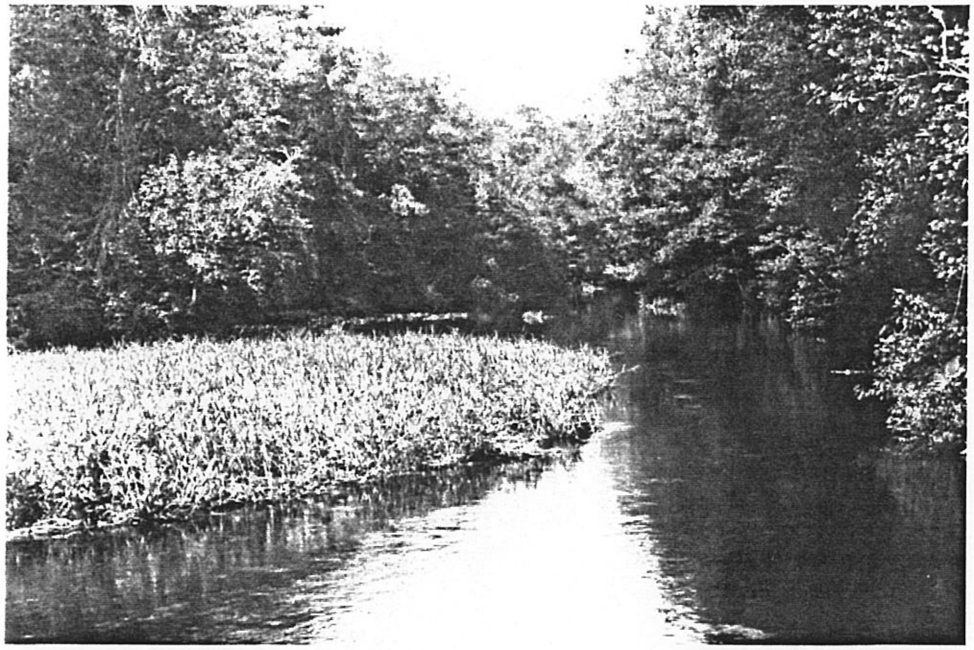


Figure 20. Station number 22 and 23 located on the Little Wekiva River.

Figure 21. Station number 24 located on the Little Wekiva River.

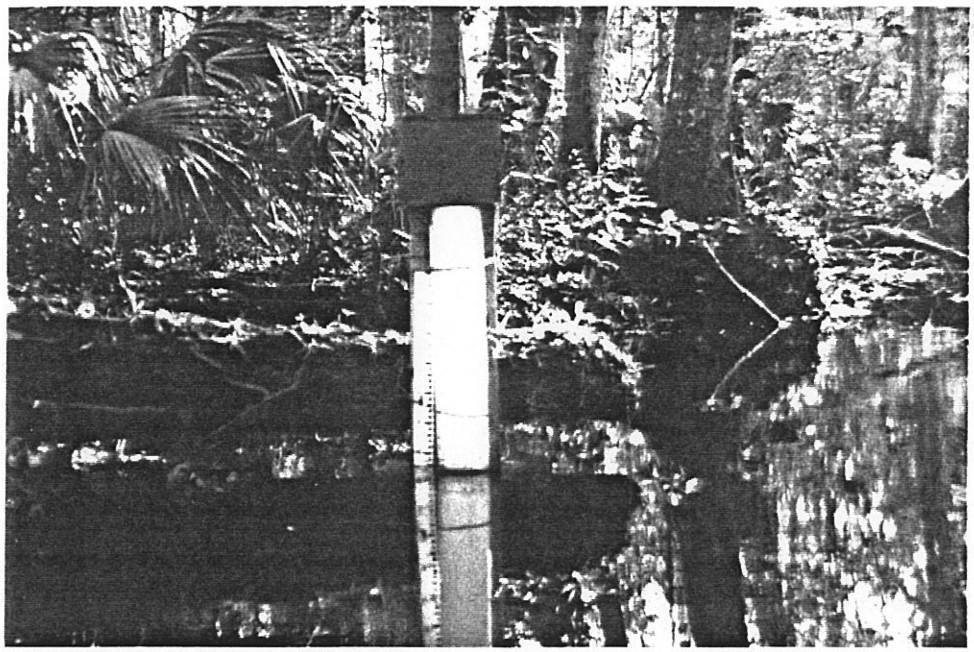


Figure 22. Station number 25 located on the Little Wekiva River.

Figure 23. Station number 2 located on Alexander Springs.

Table 2. Location and description of sampling stations in the survey streams.

Stream	County	Station	Description
Alexander Springs	Lake	1	Bridge at State Road 445
		2	2 km above National Forest Service Road 52 boat ramp
		3	2 km below National Forest Service Road 52 boat ramp
Ichetucknee Springs	Columbia	1	100 m below headwater springs
		2	Midway between U.S. 27 and headwater springs
		3	100 m above junction with Santa Fe River
Alligator Creek	Bradford	1	Bridge at U.S. 301
		2	Midway between U.S. 301 and Lake Rowell
		3	100 m above confluence with Lake Rowell
Rock Spring Run	Orange	1	Kelly Park below headwater spring
		2	Midway between Kelly Park and the Wekiva River
		3	100 m above confluence with Wekiva River
Little Econlock-hatchee	Orange-Seminole	1	Bridge at Highway 50
		2	Bridge at State Road 520
		3	Bridge at Lockwood Road
Wacissa River	Jefferson	1	100 m below headwater springs at Wacissa Park

Table 2. Continued

Stream	County	Station	Description
		2	Midway between headwater springs and Goose Pond
		3	Goose Pond Boat Ramp
Wekiva River	Orange-Seminole	1	100 m below junction of Rock Springs Run and Wekiva Springs
		2	100 m above confluence with Little Wekiva River
		3	200 m below junction with Little Wekiva River
		4	Katie's Landing
		5	0.4 km above confluence with St. Johns River
Alafia	Hillsborough	1	Highway 39 below Aldermans Ford Park
		2	Bridge at State Road 640
		3	Bridge at Bell Shoals Rd.
Reedy Creek	Orange-Osceola	1	Bridge at Interstate 4
		2	Bridge at Highway 92
		3	Bridge at Highway 531
St. Johns River	Volusia-Seminole-Lake	1	200 m above junction with Wekiva River
		2	500 m below junction with Wekiva River
Pottsburg Creek	Duval	1	Bridge at Belford Road
		2	Bridge at Highway 90

Table 2. Continued

Stream	County	Station	Description
		3	Bridge at Alt. U.S. 1
Mills Creek	Nassau	1	3 km east of Callahan
		2	Midway between Station 1 and Station 3
		3	Section 21 before Nassau River
St. Marks River	Wakulla-Leon	1	Boarder at Leon County
		2	Start of region with homes
		3	Bridge at U.S. 98
Econlock-hatchee	Orange-Seminole	1	Bridge at Highway 50
		2	Bridge at State Road 420
		3	Bridge at State Road 419
Hillsborough River	Hillsborough	1	Bridge at State Road 579
		2	Bridge at Interstate 75
		3	Bridge at State Road 582
Hogtown Creek	Alachua	1	Bridge at State Road 232A
		2	Bridge at State Road 338
		3	Bridge at State Road 26
Upper Santa Fe River	Bradford-Union	1	Bridge at State Road 235
		2	Bridge at State Road 121
		3	Bridge at State Road 241

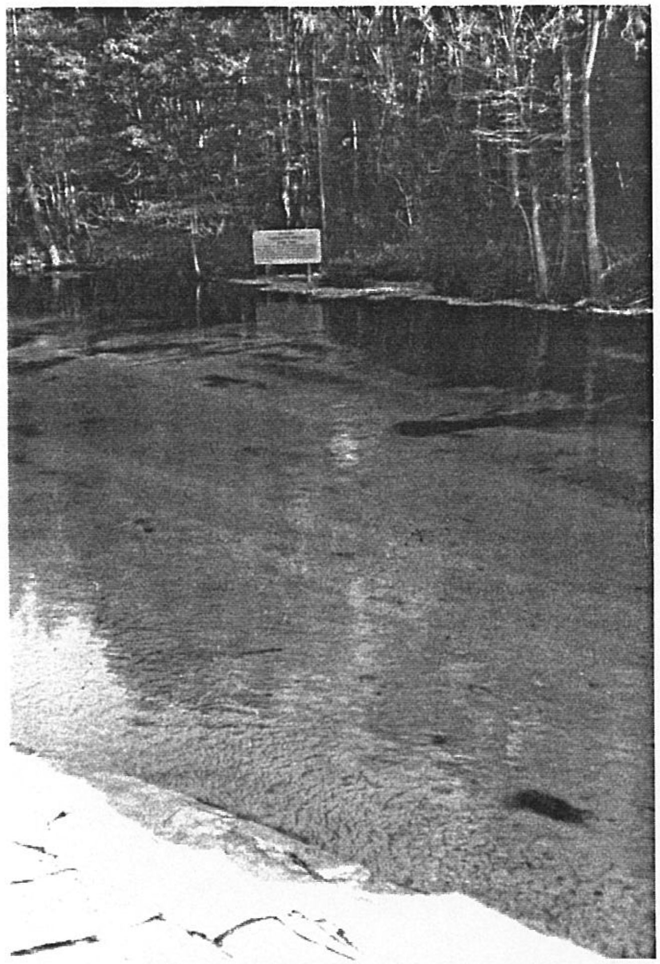


Figure 24. Station number 2 located on the Ichetucknee Springs.

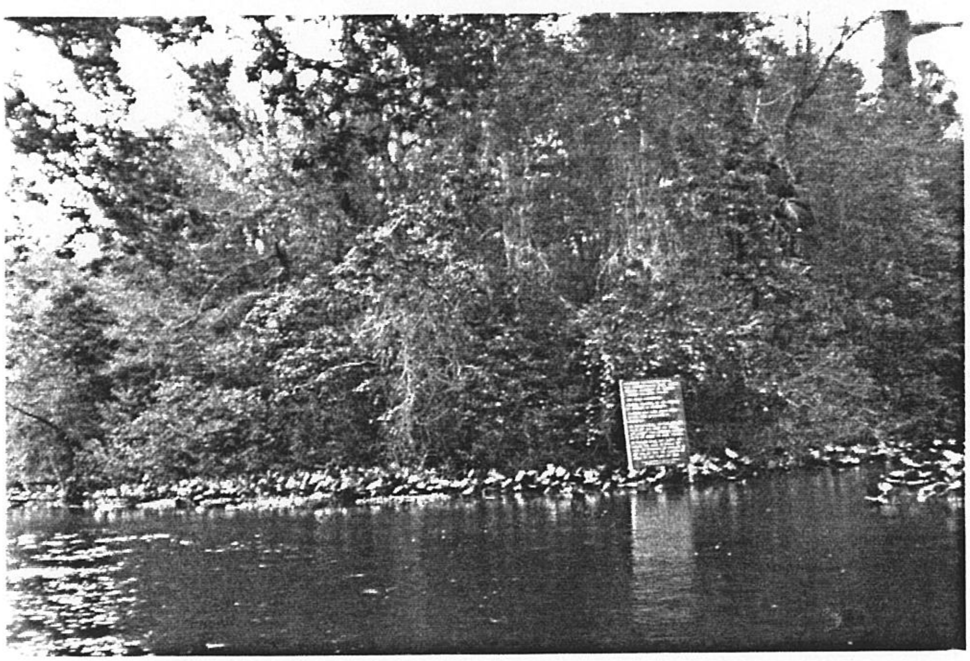


Figure 25. Station number 3 located on the Rock Springs.

Figure 26. Station number 2 located on the Wacissa River.

Figure 27. Station number 3 located on the Alligator Creek.

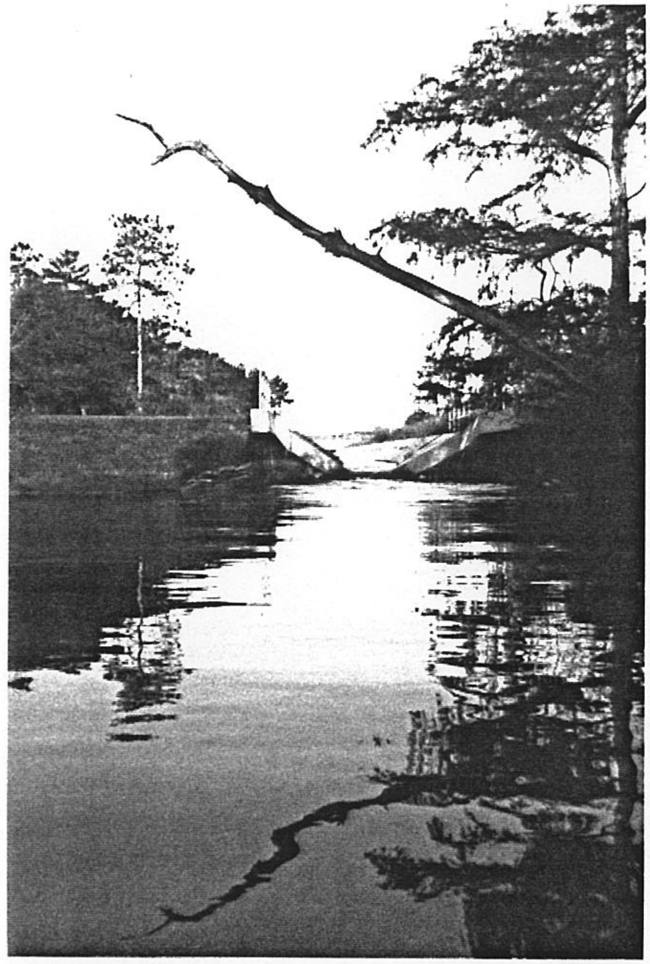


Figure 28. Iron bridge sewage treatment discharge just above station number 2 located on the Little Econlockhatchee River.

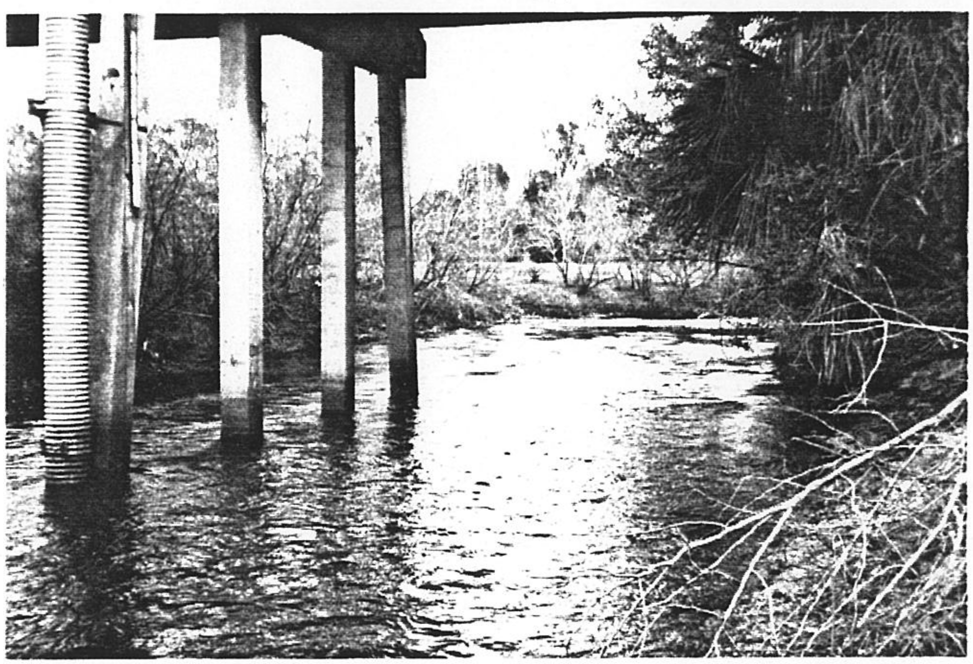


Figure 29. Station number 2 located on the Alafia River.

of 1 mg/L. The Wekiva River (Figure 30) was also added to the study to determine what effects discharges from the Little Wekiva River might be having further downstream.

Eight more streams were added to the study after December 1985 in order to provide further information on how the biota of Florida streams respond to different levels of nutrient enrichment (Table 2). Reedy Creek (Figure 31), Pottsburg Creek (Figure 32), and Mills Creek (Figure 33) were selected for study because each stream received nutrients from anthropogenic sources. The upper Hillsborough River (Figure 34), Hogtown Creek (Figure 35), and the upper Santa Fe River (Figure 36) were chosen because these streams drain naturally occurring phosphatic soils. The St. Marks River (Figure 37) was added to the study because the stream is spring-fed and lightly impacted by development. The upper Econlockhatchee River (Figure 38) was studied to provide a comparison with the Little Econlockhatchee River, which was impacted by treated wastewater discharges from the Iron Bridge Sewage Treatment Plant. Additional sampling stations were placed along the length of the Wekiva River and at Wekiva Falls to provide a better assessment of the effect of discharges from the Little Wekiva River on water quality in the Wekiva River. Sampling stations were also placed in the St. Johns River upstream and downstream of the confluence with the Wekiva River.

Water Quality

Water quality samples were collected monthly between October 1984 and December 1985 from all sampling stations established

Figure 30. Station number 4 located on the Wekiva River.

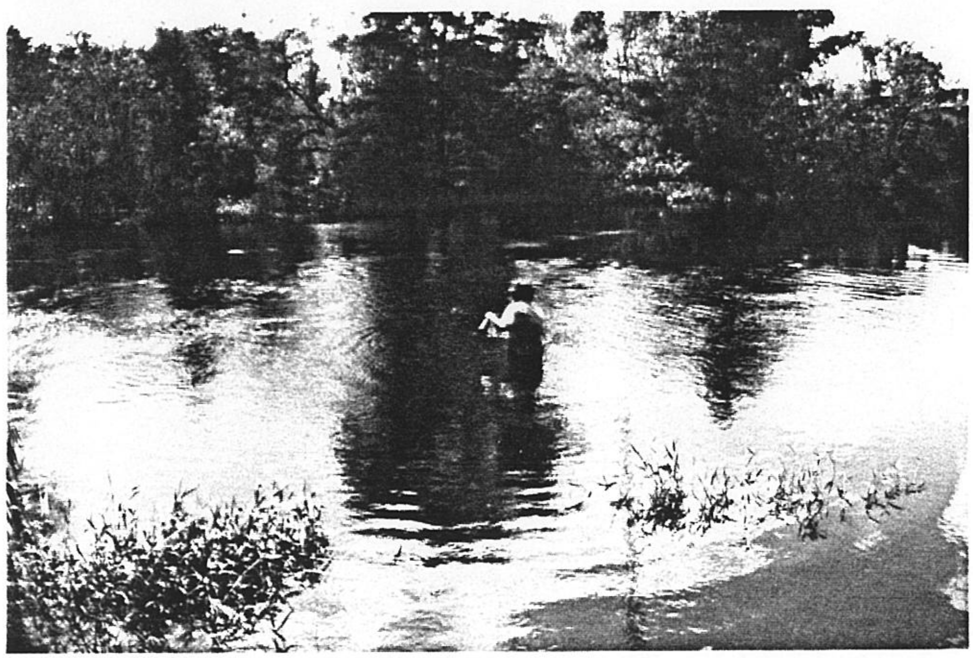


Figure 31. Station number 2 located on Reedy Creek.

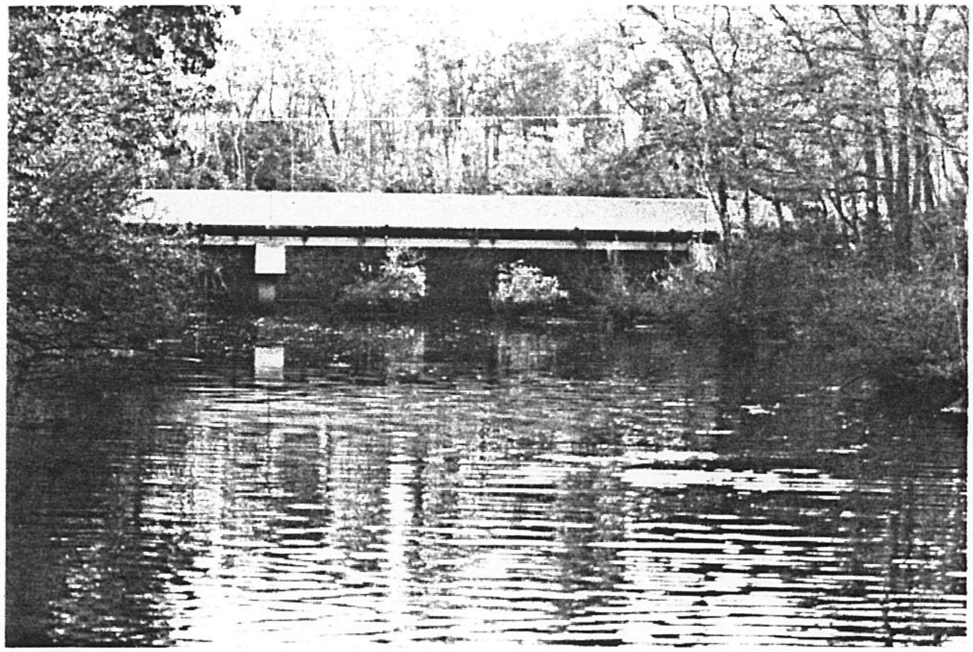


Figure 32. Station number 1 located on Pottsburg Creek.

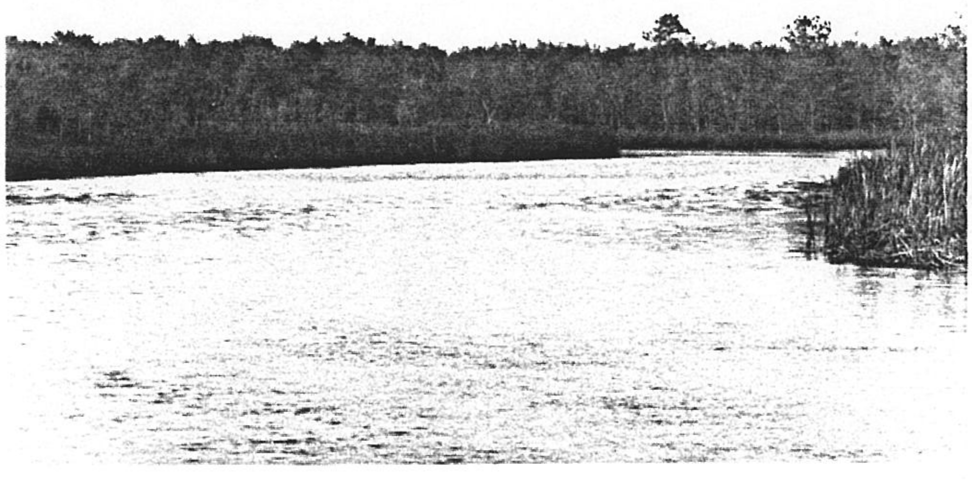


Figure 33. Station number 3 located on Mills Creek.

Figure 34. Station number 2 located on the Hillsborough River.

Figure 35. Station number 3 located on Hogtown Creek.

Figure 36.

Station number 2 located on the Santa Fe River.

Figure 37.

Station number 2 located on the St. Marks River.

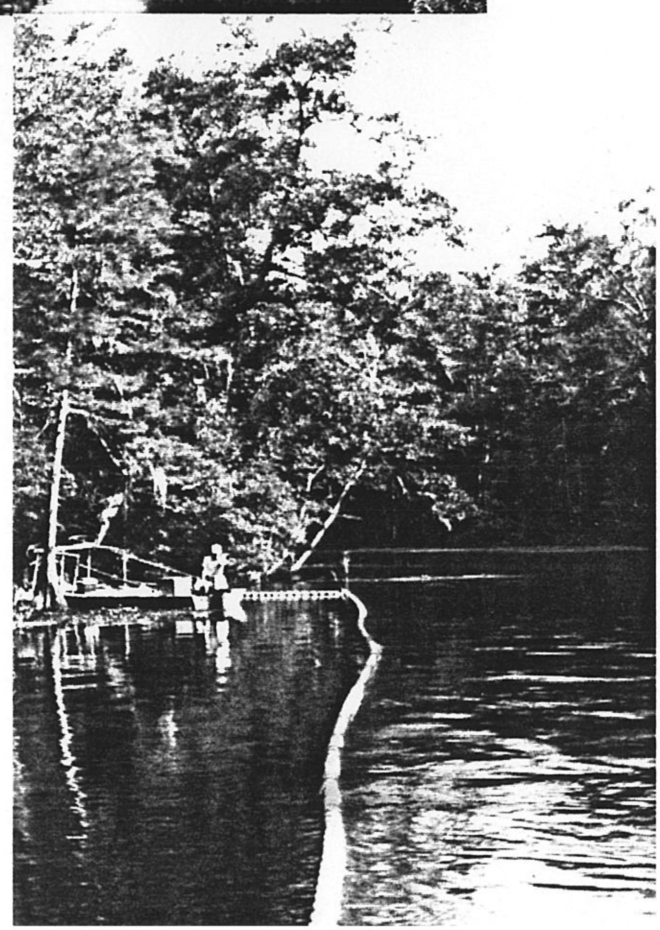


Figure 38. Station number 3 located on the Econlockhatchee River.

along the Little Wekiva River. After December 1985, samples were collected every two months, and we ceased sampling at Stations 2, 5, 8, 11, 14, 15, 18, 19, 20, 22, 23, and 24. Water quality samples were collected from a mid-stream location at three stations (headwater, mid-stream, and stream mouth) in each survey stream every two months between May 1985 and January 1987. Spring-fed streams (Alexander Springs, Ichetucknee Springs, Rock Springs Run, St. Marks River, Little Wekiva River, and Wekiva River) were studied from near their origin at the springs to their mouth. Other streams were studied only in specific reaches to eliminate downstream pollution sources (Table 2). Dissolved oxygen and temperature were measured just below the water surface (0.1 m) with a Yellow Springs Instrument Model 57 oxygen-temperature meter. Water velocities were measured by use of a Marsh-McBirney Model 201m portable current meter, and stream discharge was estimated by use of the procedures described by Platts et al. (1983). Water samples were collected from just below the surface in 1-L, acid-cleaned, nalgene bottles. Water samples were then placed on ice and transported to the laboratory for analysis.

At the laboratory, pH was measured by use of an Orion Model 601A pH meter calibrated against buffers at 4.0, 7.0, and 10.0. Total alkalinity (mg/L as $CaCO_3$) was determined by titration with 0.02 N sulfuric acid (A.P.H.A. 1981). To standardize titrations and avoid interference from silicates, phosphates, and other materials, all samples were titrated to a pH of 4.5 (A.P.H.A. 1981). Specific conductance (uS/cm at 25 ^{o}C) was measured by using a Yellow Springs Instrument Company Model 31 conductivity bridge. Chloride (mg/L) was measured by titrating with 0.0141 N mercuric nitrate and using diphenylcarbazone as the endpoint indicator (A.P.H.A. 1981). Silica concentrations (mg/L) were determined by using the heteropoly blue method (A.P.H.A. 1981), and total iron (mg/L) concentrations were determined by using the ferrozine method (Hach Chemical Company 1975). Nitrate (mg N/L) was determined using the cadmium reduction method, and total kjeldahl nitrogen (mg N/L) was determined using standard methods (A.P.H.A. 1981). Total nitrogen concentrations (mg N/L) were determined by using a modified Kjeldahl technique (Nelson and Sommers 1975). Total phosphorus concentrations (mg/L) were determined by using the procedures of Murphy and Riley (1962) with a persulfate digestion (Menzel and Corwin 1965). Total suspended solids, organic suspended solids, and inorganic suspended solids were determined by use of standard methods (A.P.H.A. 1981).

Following filtration through a Gelman type A-E glass fiber filter, water samples were analyzed for sulfate, color, sodium, potassium, calcium, and magnesium. Sulfate concentrations (mg/L) were determined by use of a turbidimetric method, and color (Pt-Co units) was determined by using the platinum-cobalt method with Nessler tubes (A.P.H.A. 1981). Sodium and potassium concentrations (mg/L) were determined by flame photometry, and calcium and magnesium concentrations (mg/L) were determined by atomic absorption spectroscopy (A.P.H.A. 1981).

Aquatic Plants

The biomass of suspended algae at each station was estimated by measuring chlorophyll a concentrations (mg/m^3). For chlorophyll analysis, a measured volume of stream water was filtered through a Gelman type A-E glass fiber filter. Filters were stored over desiccant and frozen until analyzed. Chlorophyll a and phaeophytin concentrations were determined by standard methods (A.P.H.A. 1981). To determine the potential biomass of suspended algae and to test the hypothesis that suspended algal populations in Florida streams were not limited by nutrients, stream and spring water samples with their indigenous algal populations were cultured under controlled conditions for up to 14 days using procedures modified from Burkholder-Crecco and Bachmann (1979). Increases in algal biomass were detected by measuring chlorophyll a concentrations.

Aquatic macrophytes including large algae such as Cladophora sp., Lynbya sp., and Chara sp., were sampled from one to three times between March 1985 and September 1986. All sampling was conducted between March and November of each year because this period corresponds to the period of peak plant abundance in Florida's subtropical streams. Aquatic vegetation was sampled by the use of two boats and divers. One boat started at the mouth of the stream or stream-reach to be studied, and the other boat started at the headwaters of the stream or stream-reach. Plants were sampled at roughly uniform intervals as the boats were motored at idle speed from one to seven minutes. The time of movement was adjusted for the length of each stream so that a minimum of 20 stations (maximum of 90 in the Little Wekiva River) were sampled in each stream. A sampling transect was established perpendicular to the main line of stream flow at each station. Stream width was measured by use of either measuring tapes or calibrated range finders. All species of aquatic macrophytes present along the transect were recorded. Stream depth, tree canopy coverage, and the above-ground standing crop of aquatic macrophytes were then measured at five equally spaced locations starting from the middle of the stream channel. At each sampling location, a 0.25-m^2 quadrat was randomly dropped, and the divers removed all vegetation present within the quadrat. The sampled vegetation was then spun in nylon mesh bags to remove excess water and weighed to the nearest 0.1 kg. Tree canopy coverage was visually estimated as either 0, 50, or 100% cover above each plant sampling site. The five canopy coverage values, the above-ground macrophyte standing crop values, and the water depths were then averaged to provide a mean value for each sampling transect.

Composite plant samples from the streams were analyzed using the methods described by Canfield et al. (1983) to determine average plant tissue nutrient levels. The water content of all macrophytes was assumed to be 95%. The content of total phosphorus in the plant tissues ranged from 2.4 to 7.5 mg/g dry weight and total nitrogen levels ranged from 12 to 32 mg/g dry weight. Because these values were similar to those found for aquatic macrophytes in other Florida waters (Canfield et al. 1983), mean tissue nutrient levels for total phosphorus (3.7 mg/g dry weight) and total nitrogen (23 mg/g dry weight) were used with the average above-ground standing crop values expressed as dry weight to determine the total mass of nutrients associated with the aquatic macrophytes in each stream. The annual total phosphorus and total nitrogen discharge rates for each stream were calculated according to the methods of Platts et al. (1983) for the last downstream station.

Periphyton abundance was estimated on 473 macrophyte samples collected from 14 streams. Aquatic macrophtyes in the streams were collected randomly from the headwaters to the stream mouth on one to three sampling dates during the growing seasons of 1985 and 1986; seven to one hundred samples were collected per stream depending upon the abundance of macrophytes in the stream. Periphyton abundance was estimated by use of a method modified from Moss (1981). Approximately 100 g wet weight of each macrophyte species was carefully cut from 0.1 to 0.5 m below the water surface, placed in 1-L wide mouth nalgene bottles containing 500 ml of tap water and stored on ice until processed (within 7 hr of collection).

At the laboratory, periphyton was removed from plant samples by vigorously shaking samples for 30 seconds. The supernatant was then filtered through a 1.0 mm screen into a 5-L nalgene bucket. This procedure was repeated three times for each plant sample after adding 500 ml of tap water each time. Plant samples were saved after periphyton was removed, and the surface area was measured for each plant segment. The total supernatant (approximately 1500 ml) was subsampled and filtered through

Gelman type A-E glass fiber filters. Filters were then processed using the procedures for planktonic algae to determine the chlorophyll *a* content. Periphyton abundance was expressed as chlorophyll *a*/m^2 of plant surface.

The surface areas of our plant samples were measured by use of a method modified from Harrod and Hall (1962). We developed a relationship between measured plant surface area and the weight of a thin layer of a non-ionic oil concentrate adjuvant (Kammo) covering the plant sample. Surface areas were measured for samples of *Nuphar luteum*, *Brachiaria mutica*, *Hydrilla verticillata*, *Ceratophyllum demersum*, and *Chara* sp. by tracing each plant part on paper and measuring their area with a polar planimeter. The calculated regression equation based on the surfactant weight necessary to form a thin film on a minimum of four samples of each plant type versus the measured surface area was:

$$\log SA = 1.72 + 0.44 \log SW \qquad R^2 = 0.86 \qquad n = 34$$

where SA is the plant surface area (cm^2) and SW is the weight (g) of surfactant on the plant sample. Each plant sample collected from the streams was dipped in surfactant, and the regression was used to determine the total surface area of each plant sample.

We also evaluated our method of periphyton removal for five major macrophtyes: *Eichhornia crassipes*, *Nuphar luteum*, *Hydrilla verticillata*, *Paspalidium geminatum*, and *Utricularia* spp. Three replicate samples of each plant were collected and processed as above. Each sample, however, was subjected to 20 30-second washes, and the supernatant from each wash was analyzed for chlorophyll a content. Each macrophyte sample was dried for 24 hr at 60 ^{o}C and weighed. Periphyton abundance (mg chlorophyll a per gram dry weight of macrophyte) was then calculated for each wash. The rate of periphyton removal was similar for all plant types (Figure 39). The mean percentage of total periphyton biomass (sum of all 20 washes) removed after three washes averaged 65% and ranged from 43 to 82%. Because the rate of removal and the percentage of periphyton removed after three washes were consistent among all macrophyte types tested, we concluded three washes of each plant sample were sufficient for obtaining comparative data between stations and different streams.

Macroinvertebrates

Macroinvertebrate abundance in the Little Wekiva River and select survey streams was estimated by measuring invertebrate drift. Sampling procedures were modified from those used by Zimmer and Bachmann (1978). Drift organisms were collected at water quality sampling stations by use of cylindrical drift nets. Nets were approximately 2 m long and 30 cm diameter; mesh size was 1.0 mm. Nets were tapered to a 12 cm circular opening at the anterior end. Nets were placed at mid-depth below the water surface and left in the stream for 24 hr. The velocity of flow at net openings was measured when the net was set and when the net was retrieved. Samples were collected, placed in plastic

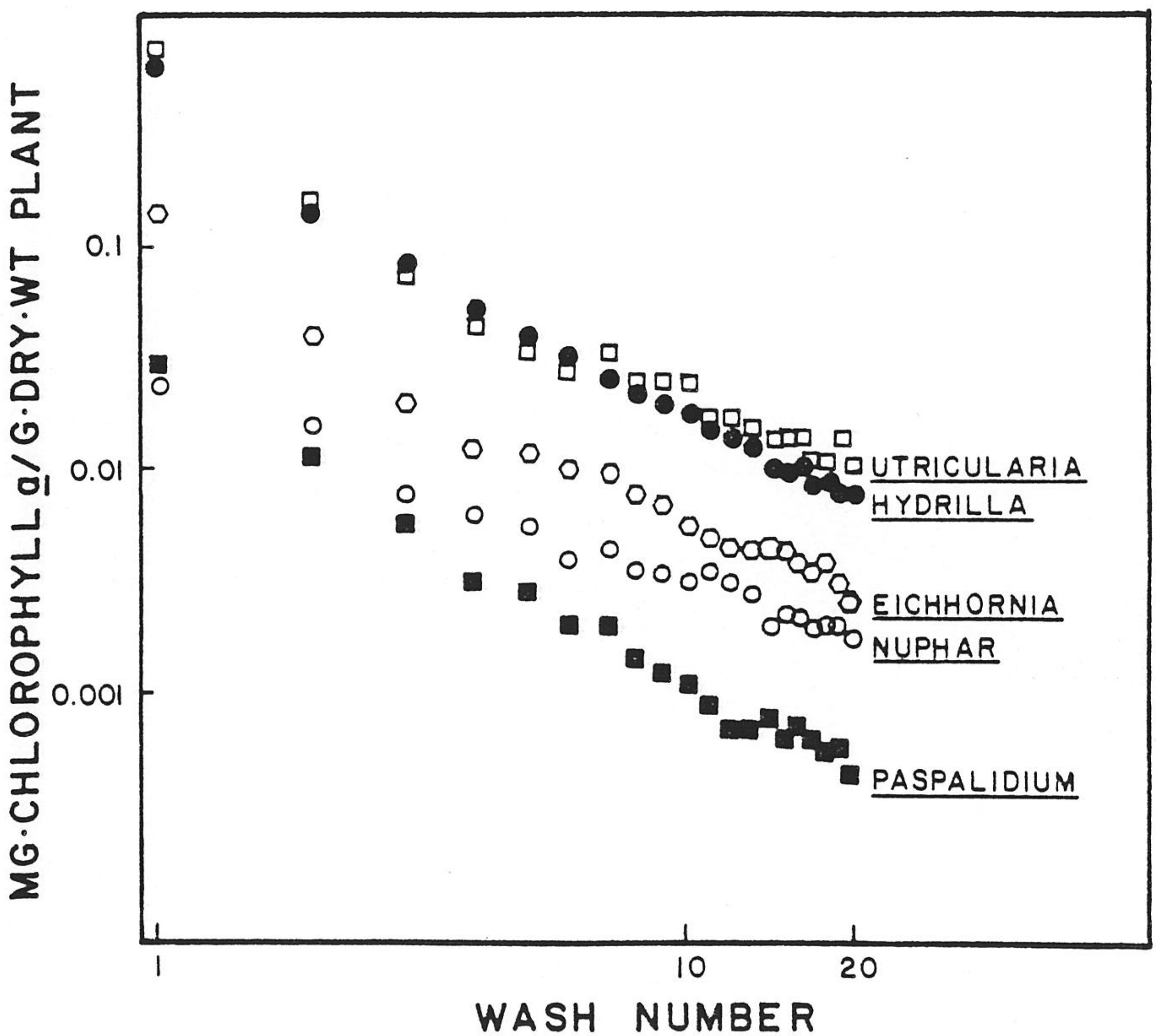


Figure 39. Relation between periphyton removal (chlorophyll a/g dry.wt of plant) and wash number.

bags, preserved on ice, and returned to the laboratory where samples were picked by hand to remove invertebrates. All organisms were counted and weighed. Macroinvertebrate drift was measured monthly at 11 stations along the Little Wekiva River between October 1984 and September 1985. Eight stations were sampled in 1986. Macroinvertebrate drift in select survey streams was measured at the three water quality sampling stations.

Fish

Fish abundance in the Little Wekiva River and other survey streams was estimated by use of a modification of the Zippin multiple removal technique, which is used by the U.S. Forest Service and the U.S. Fish and Wildlife Service for assessing fish populations in small streams (Armour et al. 1983; Platts et al. 1983). Two to six sections ranging in length from 27 to 230 m (mean 95 m) and width from 3 to 32 m (mean 14 m) were sampled in each stream on two or three dates between May 1985 and February 1987. Where possible, representative sampling reaches were selected in both open and closed forest canopy sections within each stream. Sampling sites were blocked at their upstream and downstream ends by use of blocknets to prevent the escape of fish during sampling. Blocknets were 3.4 m deep and had a bar mesh size of 3 mm.

Fish were collected from each sampling site by use of electrofishing. Electrofishing was conducted either from a boat or by wading the smaller stream sections with hand-held electrodes. Power was supplied by use of a 5 kw generator. High voltage pulsed AC current produced by a Coffelt Model VVP-15 electroshocker unit (Coffelt Electronics Company, Englewood, Colorado) was used to shock fish. Fish were collected from the entire area of each sampling site during four consecutive electrofishing removals. All fish collected were identified to species, sorted into 25 mm total length (TL) size groups, counted, and weighed. Fish over 100 g were weighed to the nearest gram and fish less than 100 g were weighed to the nearest 0.1 g. Estimates of total and harvestable fish stock (numbers/ha) and standing crop (kg/ha) were obtained by summing the results of the four electrofishing removals. Fish designated as harvestable fish are: yellow bullhead (Ictalurus natalis) > 250 mm TL, brown bullhead (Ictalurus nebulosus) > 250 mm TL, white catfish (Ictalurus catus) > 250 mm TL, channel catfish (Ictalurus punctatus) > 250 mm TL, redbreasted sunfish (Lepomis auritus) > 150 mm TL, warmouth (Lepomis gulosus) > 150 mm TL, bluegill (Lepomis macrochirus) > 150 mm TL, redear sunfish (Lepomis microlophus) > 150 mm TL, spotted sunfish (Lepomis punctatus) > 150 mm TL, largemouth bass (Micropterus salmoides) > 250 mm TL, suwannee bass (Micropterus notius) > 250 mm TL, and black crappie (Pomoxis nigromaculatus) > 150 mm TL. Otoliths (sagittae) were removed from subsamples of largemouth bass and redbreasted sunfish, the two major sport fish in the sampled streams, and examined in whole-view according to the methods of Hoyer et al. (1985) for determinations of age and growth.

STREAM MORPHOMETRY

The Little Wekiva River, like many streams in Florida, is a small, shallow, low-gradient stream (Table 3; Beck 1965; Florida State Board of Conservation 1966; Bass and Cox 1985). The stream flows for 17 km between Lotus Lake and the Wekiva River. The stream channel varies in width from 3 to 50 m but averages < 17 m (Table 3). Many reaches of the stream are shaded by trees and bushes and do not support extensive growths of aquatic vegetation. Sections of the river lacking an extensive forest canopy, however, typically support aquatic vegetation. Water depths in the main channel during 1985 and 1986 ranged from 0.1 m to 3.5 m but averaged < 1.5 m, which is also typical of many small Florida streams (Table 3). The Little Wekiva River drops from an elevation of 18.6 m mean sea level (MSL) at Lotus Lake to approximately 3.7 m MSL at its confluence with the Wekiva River for an overall stream gradient of 0.88 m/km. The nature of the Little Wekiva River, however, is different in its upper and lower reaches because of regional geology, hydrology, and human influences.

Upper Little Wekiva River

The upper Little Wekiva River from Lotus Lake to State Road 434 flows through a physiographic district known as the Apopka Hills (Brooks 1981). The Apopka Hills are an elevated sandhill region that has been strongly modified by karst processes. The

Table 3. Length, mean width, mean depth, and mean hydraulic residence time of each study stream for 1985 and 1986.

Stream	Year	Length (km)	Width (m)	Depth (m)	Residence Time (days)
Little Wekiva	1985	17.0	14	0.5	0.5
	1986		16	1.0	1.0
Alexander Springs	1985	13.0	43	0.9	1.2
	1986		45	0.8	1.2
Ichetucknee	1985	7.5	24	1.1	0.2
	1986		26	1.2	0.4
Alligator Creek	1985	5.0	7.2	0.6	0.2
	1986		6.8	0.5	0.2
Rock Springs	1985	12.0	24	0.7	0.9
	1986		23	0.8	0.4
Little Econlockhatchee	1985	7.5	10	1.4	0.2
	1986		9.4	1.2	1.2
Wacissa	1985	16.0	50	1.2	1.2
	1986		83	1.2	1.3
Wekiva	1985	18.5	57	0.9	0.9
	1986		51	0.9	1.1
Alafia	1985	16.0	14	0.9	1.1
	1986		18	1.7	0.5
Reedy	1986	7.5	10	0.8	0.1
Pottsburg	1986	9.5	28	1.4	0.2

Table 3. (Cont.).

Stream	Year	Length (km)	Width (m)	Depth (m)	Residence Time (days)
Mills Creek	1986	13.5	18	2.1	1.5
St. Marks	1986	10.0	44	1.7	0.4
Econlockhatchee	1986	11.0	10	1.0	0.1
Hillsborough	1986	10.0	31	1.9	0.4
Hogtown	1986	3.0	4.7	0.2	0.2
Santa Fe	1986	16.0	14	0.9	0.2

Hawthorn Formation is the dominant geologic formation and consists primarily of sand, silty-sand, and clay with phosphorite granules (Brooks 1981). The upper Little Wekiva River descends from an elevation of 18.6 m MSL at Lotus Lake to approximately 6.1 m MSL at State Road 434 for a stream gradient of 1.6 m/km. The stream channel in the Apopka Hills is narrow, ranging from less than 3 m to approximately 18 m (average 5.8 m). Many areas of the upper Little Wekiva River are shaded by trees and do not support rooted aquatic vegetation. Stream banks along the upper Little Wekiva River, however, are also steep (slopes > 1:2 in many areas) and subject to erosion, which encourages the downstream movement of large amounts of sand. Water depths ranged from 0.1 m to 1.4 m during 1985 (average 0.4 m) and 1986 (average 1.0 m), but high water marks on bridges indicated water levels can rise well above 2 m throughout most of the upper Little Wekiva during flood events. The bottom substrates are primarily shifting sand and hard clay; substrates that do not favor the establishment of permanent beds of rooted aquatic plants (Butcher 1933).

The upper Little Wekiva River has been extensively modified over the last century by human activities and is now best described as an urban stream. Some of the current morphometric characteristics of the stream are a direct result of past cultural activities. By 1940, a considerable amount of the natural vegetation on the uplands had been replaced by citrus. Agricultural activities (e.g., logging) along the stream had also contributed to a reduction in the abundance of streambank vegetation (Figure 40), and some sections of the river were channelized to improve drainage (Figure 40). During the 1960's, 1970's, and 1980's, urban development increased rapidly in the upper Little Wekiva River watershed, and numerous homes were built near the stream. Development of the banks of the upper Little Wekiva River resulted in the removal or thinning of the streambank vegetation, the drainage and channelization of wetlands, stream channelization, and an increased discharge of urban runoff (Figure 41). These alterations and the earlier agricultural activities have all contributed to severe erosion problems that now occur along the length of the upper Little Wekiva River. For example, we observed during the study the loss of large amounts of land to the stream immediately below the Seaboard Coast Line Railroad bridge (Figure 42) and from the backyards of several residences located between Station 10 and Station 11. In many areas where erosion is occurring, homeowners and various governmental agencies have replaced lost soil with new soil, rocks, and other types of debris in an attempt to reduce erosional losses. Many of these efforts, however, have been ineffectual because there is now insufficient streambank vegetation to hold the soil or prevent erosion from regions downstream of the area where remedial efforts have occurred. The net result of all this has been the increased downstream movement of large amounts of sand.

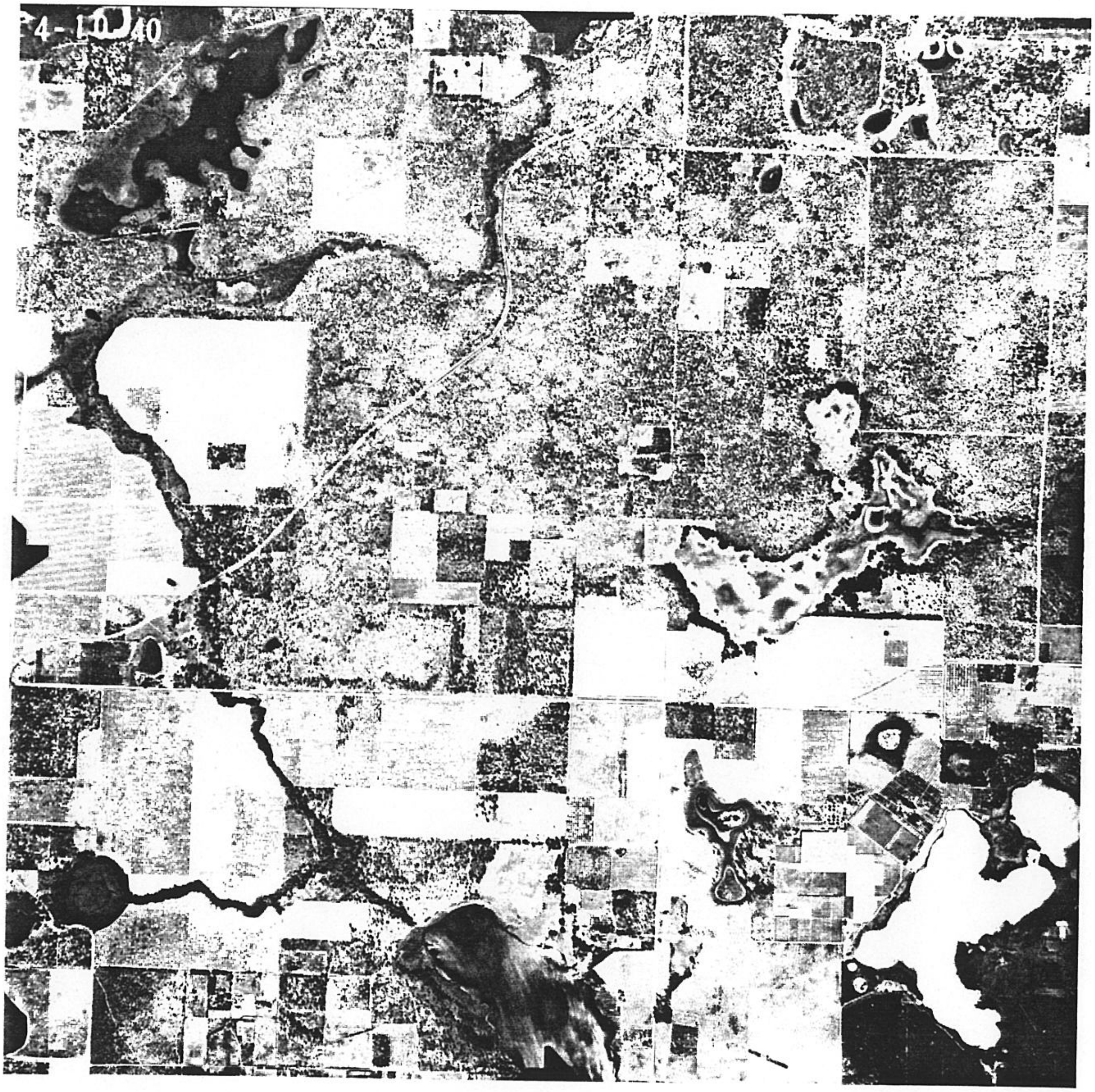


Figure 40. Upper Little Wekiva River in 1940.

Figure 41. Development of the Upper Little Wekiva River in 1971.

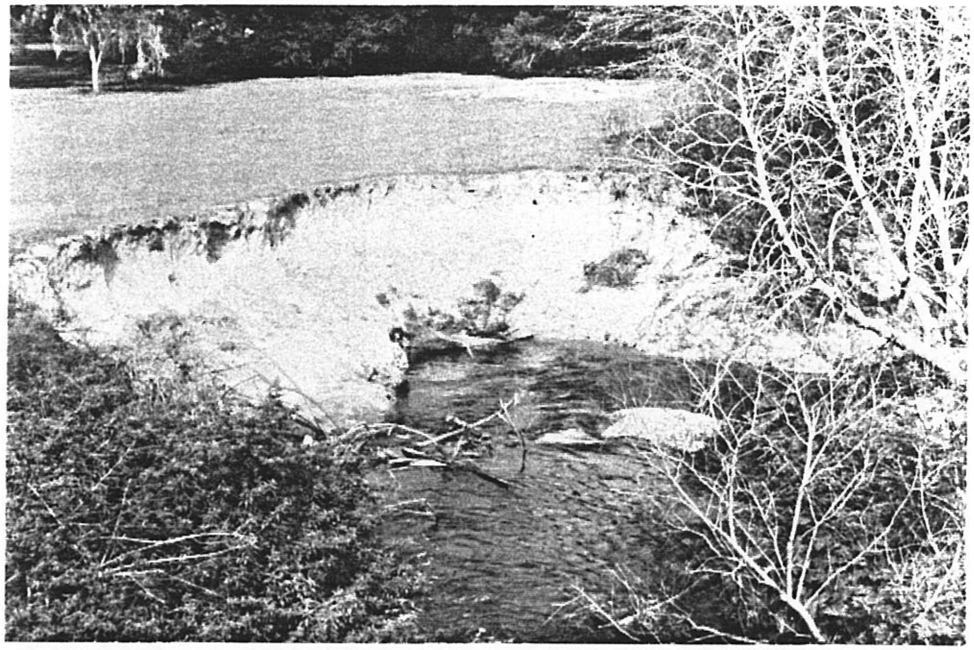


Figure 42. Erosion below Seaboard Coast Line railroad bridge located over the Little Wekiva River.

Lower Little Wekiva River

The lower Little Wekiva River from Sanlando Spring to the Wekiva River flows through the St. Johns River Offset (also called the Wekiva Plain) physiographic district. The St. Johns River Offset is a portion of the St. Johns River valley. The region is very flat and swampy. The natural vegetation is dominated by swamp forest with numerous cabbage palms (*Sabal palmetto*) on the flood plain. The geology is primarily estuarine and riverine deposits, but limestone occurs near the surface in some areas (Brooks 1981). Ground water discharges via springs occur in many areas but are especially common where the St. Johns River Offset abuts the base of elevated sandhills. The lower Little Wekiva River has a channel gradient of approximately 0.26 m/km. The stream receives major inputs of groundwater via Sanlando Spring, Palm Spring, and Starbuck Spring as it flows into the St. Johns River Offset. Channel widths in this section of the stream vary from 5 m near Sanlando Spring to over 80 m downstream of Starbuck Spring, but the river narrows considerably below Station 18. The lower Little Wekiva River has an average channel width of 27 m. Stream banks, however, are low and the stream can overflow onto a wide flood plain downstream of Springs Landing Boulevard. Water depths along the length of the lower Little Wekiva River ranged from 0.2 m to 3.5 m during 1985 and 1986, but generally averaged 1.2 m. The bottom substrates of the lower Little Wekiva River are largely shifting sand and hard clay from Sanlando Spring to Station 18, but considerable amounts of silty-sand, silt, and mud have been trapped amongst the emergent aquatic vegetation. These substrates tend to favor the development of rooted aquatic macrophyte beds, especially beds of emergent macrophytes (Butcher 1933). Below Station 18, the bottom substrates are primarily sands, mud, and alluvial deposits.

The lower Little Wekiva River has not been altered as much as the upper Little Wekiva River, but the effects of past cultural activities on the stream are evident. By 1940, nearly all of the lower Little Wekiva River basin had been heavily logged or was being logged (Figures 43 and 44). Logging tramways crossed the lower Little Wekiva River in at least three locations and logging operations removed many of the large trees (e.g, cypress and various hardwoods) along the bank of the stream as evidenced by the stumps that remain. These activities reduced or eliminated much of the forest canopy overhanging the river, and it has only been relatively recently that trees have obtained sufficient size to effectively shade many reaches along the river.

During the 1960's and 1970's, the lower Little Wekiva River was dredged in several areas (Figures 45 and 46). Materials dredged from the stream were used for fill prior to the construction of several homes and for the construction of two large islands: one across from Starbuck Spring and one just upstream of Station 17. These dredging activities created nearly all of the deep (> 2 m) water habitat measured during this study. The stream channel between Sanlando Spring and Station 18 is

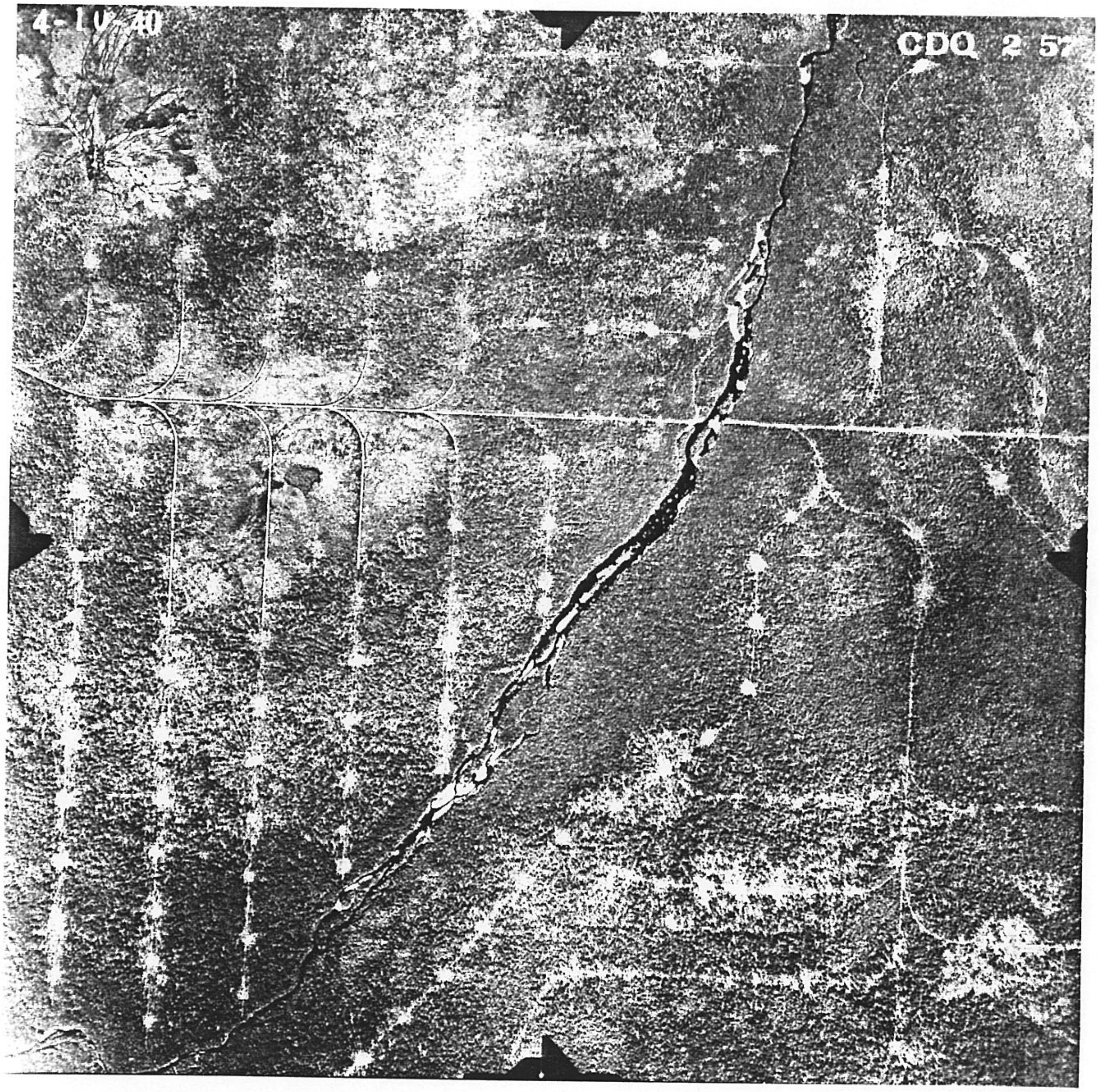


Figure 43. Logging roads in the Wekiva and Little Wekiva River basins in 1940.

Figure 44. Aquatic plants on the Little Wekiva River in 1940.

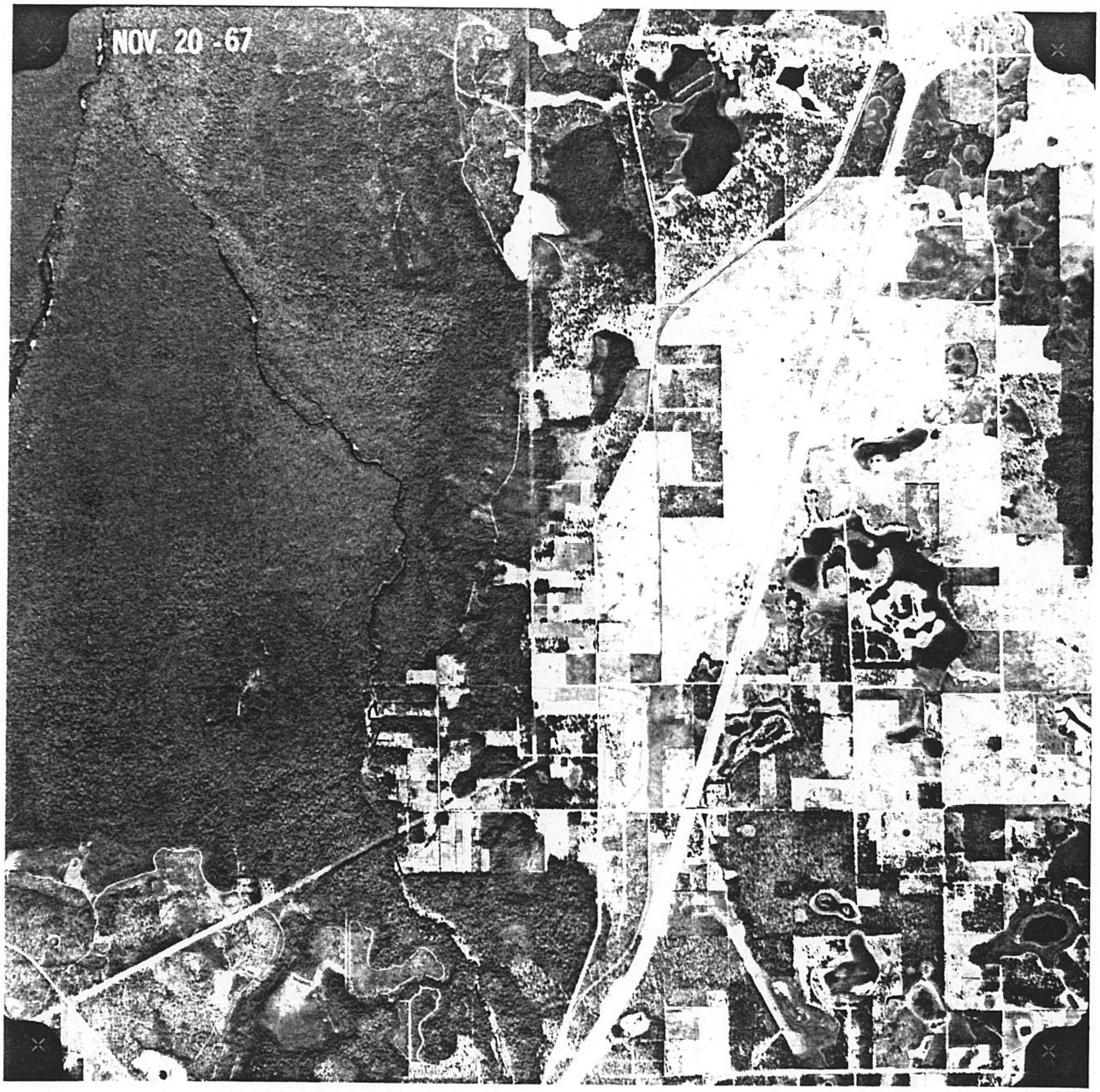


Figure 45. Dredging on the Little Wekiva River in 1967.

Figure 46. Dredging on the Little Wekiva River in 1977.

currently beginning to meander at several locations. The meandering of the stream is strongest near Starbuck Spring where the stream is attempting to cut across the upper portion of the island dredged from the river in 1977 and capture Starbuck Spring. Wood retaining walls have recently been constructed to divert the Little Wekiva River. Noticeable meanders, however, are also occurring between Station 14 and Station 17 due to the extensive growth of aquatic plants in this stretch of stream. The stream bed in this region is also very unstable and most of the deep water habitat created by dredging operations has been filled in or is in the process of being filled in by the downstream movement of large amounts of sand. These sands have come from the upper Little Wekiva River and from erosion occurring on the high sandhills along Markham Woods Road. Severe erosion has occurred where water drains off of the Interstate 4 rest area (Figure 47). At the present time, a front of moving sand is filling the deep water habitat between Station 17 and Station 18. Since October 1984, we have observed the filling of over 90 m of stream channel in front of the home of Colonel Russell F. Fisher. Water depths have decreased from over 2 m to less than 0.5 m. The shifting sand has buried some aquatic plants like spatterdock (Nuphar luteum) and tapegrass (Vallisneria americana) but has enhanced the expansion of the paragrass beds by creating shallow water habitat. Aerial photographs, however, indicate this region was originally very shallow prior to dredging (Figures 48 and 49).

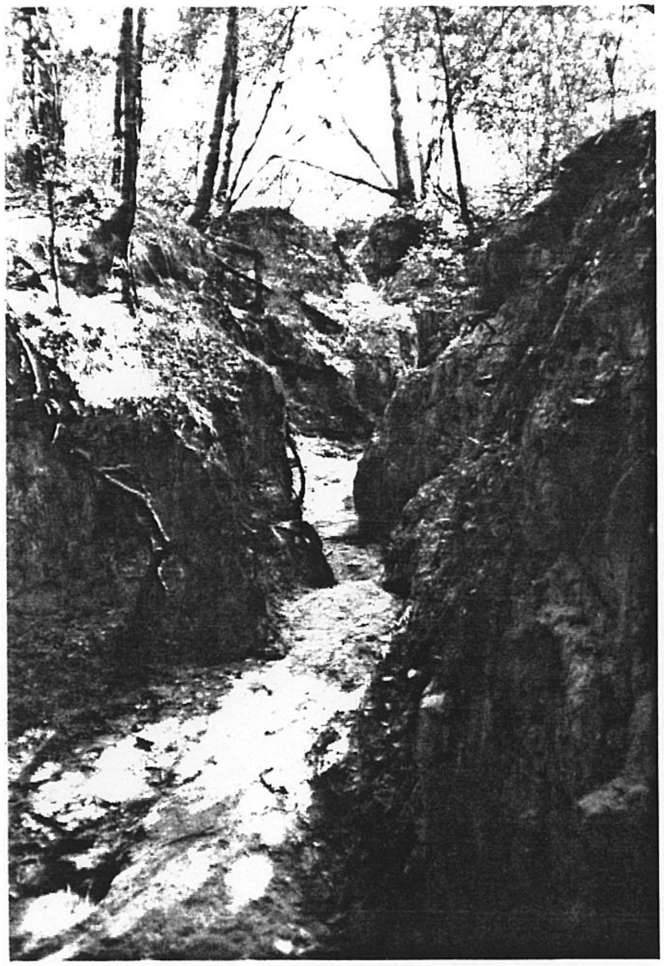


Figure 47. Erosion by Interstate 4 in the watershed of the Little Wekiva River.

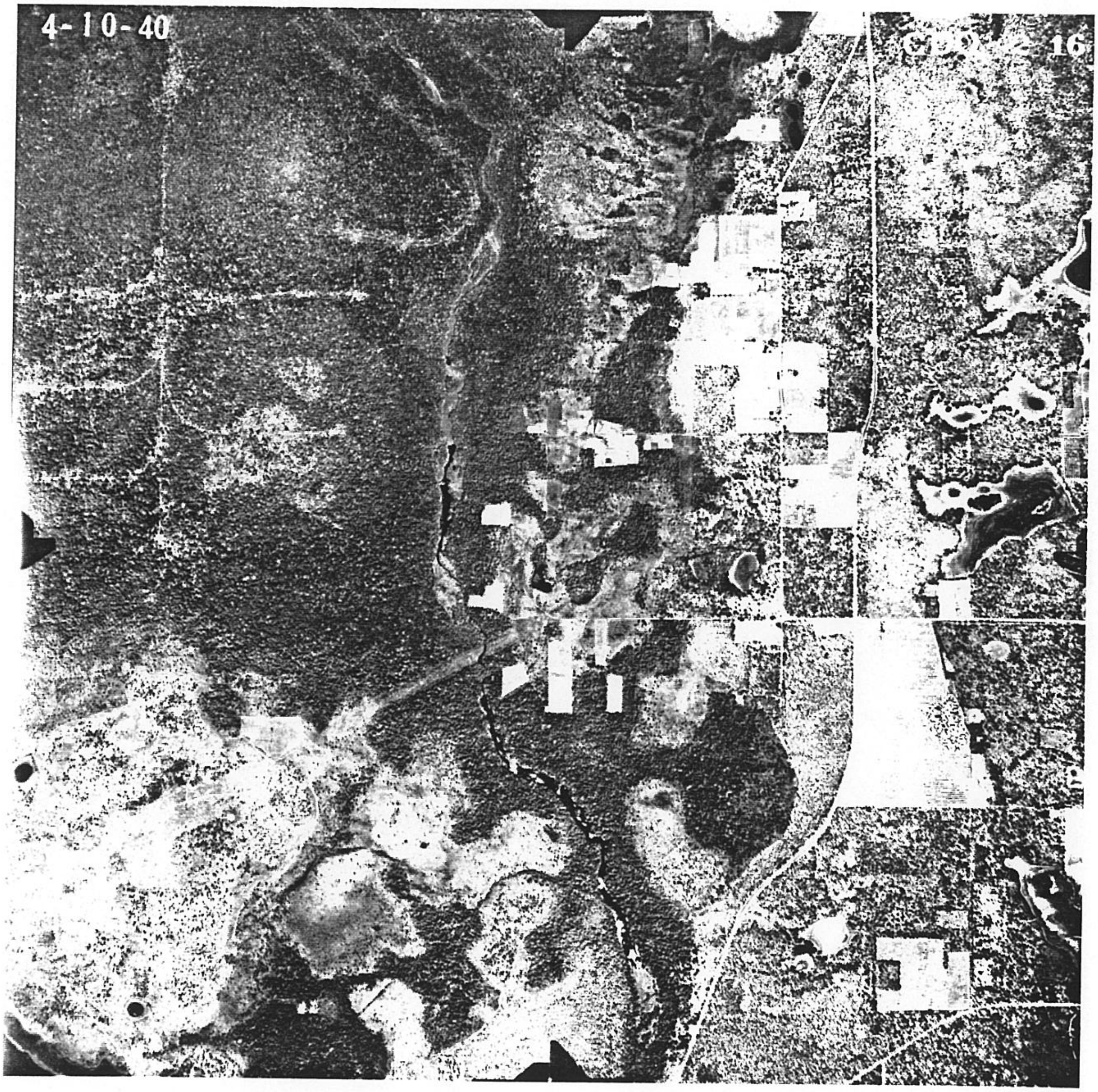


Figure 48. Sandbars on the Little Wekiva River in 1940.

Figure 49. Sandbars on the Little Wekiva River in 1957.

STREAM HYDROLOGY

The United States Geological Survey (U.S.G.S.) has monitored streamflow in the Little Wekiva River for over 11 years at a site (U.S.G.S. Station 02234990) just downstream of State Road 434 (U.S.G.S. 1985, 1986, 1987). Streamflow has been continuously monitored from February 1972 to September 1979 and from October 1982 to the current year. Stream discharge over the 11 year period of record averaged 0.99 m^3/s. The maximum recorded stream discharge was 16.8 m^3/s (July 22, 1984), and the minimum discharge was 0.05 m^3/s (May 7, 1973). During 1985 and 1986, stream discharge averaged 1.1 and 1.3 m^3/s, respectively. The maximum discharge recorded in 1985 was 4.4 m^3/s, and the minimum discharge was 0.40 m^3/s. Maximum streamflow in 1986 was 7.6 m^3/s, and the minimum recorded streamflow was 0.45 m^3/s. Streamflow along the length of the Little Wekiva River, however, varies with location, and the discharge values measured at U.S.G.S. Station 02234990 reflect only the total streamflow from the upper Little Wekiva River.

Stream Discharge

Our instantaneous stream discharge measurements made downstream of Lotus Lake and Trout Lake at Station 3 during 1985 (0.4 m^3/s) and 1986 (0.7 m^3/s) averaged 0.6 m^3/s (Table 4). Average streamflow between Station 3 and Station 12 increased over 65% due primarily to discharges from the Altamonte Springs

Table 4. Mean, minimum, and maximum instantaneous discharge (Q) for major point source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Q (m^3/s)		
Station	Year	Mean	Minimum	Maximum
2	1985	0.3 (± 0.3)	0.05	1.2
3	1985	0.4 (± 0.4)	0.05	1.9
	1986	0.7 (± 0.7)	0.08	1.5
Altamonte Springs STP	1985	0.25 (± 0.02)	0.19	0.30
	1986	0.21 (± 0.07)	0.13	0.30
6	1985	0.8 (± 0.4)	0.4	2.6
	1986	1.3 (± 1.2)	0.4	3.0
Weathersfield STP	1985	0.01 (± 0.01)	0.002	0.04
	1986	0.01 (± 0.02)	0.001	0.04
8	1985	0.5 (± 0.4)	0.2	2
High Acres	1985	0.27 (± 0.04)	0.20	0.41
	1986	0.20 (± 0.13)	0	0.26
10	1985	0.7 (± 0.4)	0.3	2.2
	1986	0.9 (± 0.8)	0.1	1.8
11	1985	1.1 (± 0.8)	0.4	4.2
12	1985	0.7 (± 0.3)	0.2	1.9
	1986	1.2 (± 1.5)	0.3	3.5
Sanlando Spring	1985	0.3 (± 0.1)	0.09	0.7
	1986	0.4 (± 0.1)	0.09	0.7
Palm Spring	1985	0.15 (± 0.02)	0.09	0.21
	1986	0.14 (± 0.01)	0.13	0.16
Starbuck Spring	1985	0.5 (± 0.1)	0.3	0.8
	1986	1.0 (± 0.2)	0.7	1.2
14	1985	1.7 (± 0.3)	1.2	2.3
15	1985	2.3 (± 0.9)	1.2	5.8
16	1985	2.0 (± 0.5)	1.2	3.8
	1986	1.9 (± 0.9)	1.2	2.8

Table 4. Continued

Station	Year	Q (m^3/s) Mean	Minimum	Maximum
17	1985	2.5 (± 0.7)	1.1	4.5
	1986	2.6 (± 1.4)	1.6	4.5
18	1985	2.4 (± 0.7)	1.0	4.4
19	1985	2.7 (± 1.1)	1.3	6.5
20	1985	3.1 (± 0.7)	1.5	5.4
21	1985	2.9 (± 0.7)	1.7	5.6
	1986	3.8 (± 1.8)	1.9	5.4
22	1985	2.7 (± 0.6)	1.7	4.4
23	1985	3.4 (± 1.0)	1.8	6.4
24	1985	2.9 (± 0.9)	1.8	6.3
25	1985	3.2 (± 0.6)	2.2	6.2
	1986	4.4 (± 1.9)	2.0	6.1

Regional Wastewater Treatment Plant (0.23 m^3/s), the Weathersfield Sewage Treatment Plant (0.01 m^3/s), and the Hi-Acres Citrus processing plant (0.24 m^3/s). Instantaneous stream discharge at Station 12, which is just downstream of U.S.G.S. Station 02234990, averaged 1 m^3/s, which compares well with the continuously measured average long-term (0.99 m^3/s) and yearly (1.1 m^3/s in 1985 and 1.3 m^3/s in 1986) discharge values measured by the United States Geological Survey. Average streamflow in the Little Wekiva River between Station 12 and Station 17 more than doubled during this study and averaged 2.6 m^3/s at Station 17 (Table 4). These increases were caused by groundwater inputs, especially spring-water from Sanlando Spring (0.4 m3/s), Palm Spring (0.15 m^3/s) and Starbuck Spring (0.8 m^3/s). Groundwater inputs and surface runoff also caused increases in the average streamflow between Station 17 and Station 25. The Little Wekiva River at its confluence with the Wekiva River had an average instantaneous discharge of 3.8 m^3/s between January 1985 and December 1986 (Table 4).

Based on the average streamflows measured between January 1985 and December 1986, water from Sanlando Spring, Palm Spring, and Starbuck Spring constituted 36% of the streamflow, and discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant constituted about 13% of the total streamflow. The Altamonte Springs Regional Wastewater Treatment Plant and the Hi-Acres Citrus plant each contributed about 6% of the total flow. The Weathersfield Sewage Treatment

Plant contributed < 1% of the water leaving the Little Wekiva River. In the upper Little Wekiva River, discharges from the Altamonte Springs Regional Wastewater Treatment Plant (23%), the Weathersfield Sewage Treatment Plant (1%), and the Hi-Acres Citrus processing plant (24%) constituted 48% of the average discharge measured at Station 12.

Streamflow in the Little Wekiva River is highly variable during different years and within a single year as shown by the data collected at U.S.G.S. Station 02234990 and the data we collected along the length of the river during 1985 and 1986 (Table 4). The percentage of the total flow contributed by the three major anthropogenic point-source discharges diminishes to less than 10% during periods of wet weather, and the importance of nonpoint source discharges of water increases significantly. During low-flow periods, discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant can constitute over 20% of the total flow leaving the Little Wekiva River (also see McClelland 1982) and virtually all the flow in the upper Little Wekiva River (Table 4). The Altamonte Springs Regional Wastewater Treatment Plant contributed about 12 to 15% of the total streamflow exiting the Little Wekiva River during the low flow periods encountered during this study. The Hi-Acres Citrus processing plant generally contributed slightly more water to the Little Wekiva River than the Altamonte Springs Regional Wastewater Treatment Plant, but the plant ceased continuous discharges to the stream in late 1986.

Streamflow in the Little Wekiva River during periods of wet weather increased progressively from Lotus Lake to the confluence with the Wekiva River, but streamflow typically decreased between Station 6 and Station 12 during low flow periods (Table 4). The loss of streamflow in the upper Little Wekiva River seemed to be caused by two factors: irrigation withdrawal and flow-loss through the stream channel. Irrigation withdrawal occurred in the upper Little Wekiva River because many adjoining homeowners used water from the stream to irrigate their lawns. Although the irrigation losses could be extremely important during severe low-flow periods, flow-loss through the stream channel is probably the more important factor.

The Apopka Hills are a major recharge area (Barraclough 1962). Barraclough (1962) determined that an area of artesian flow extended along the Little Wekiva River from the Wekiva River to a point just downstream of the Seaboard Coast Line Railroad bridge (Figure 50). Upstream of State Road 436, Barraclough (1962) determined the piezometric surface to be more than 12 m below the land surface. Since 1954, water levels in the Floridan aquifer have declined significantly (Rodis and Munch 1983) and there is some evidence that flows from the major springs in the St. Johns River Offset have declined (The Friends of the Wekiva River, Inc. 1985). For example, flow measurements from 1974 to 1980 averaged 0.53 m^3/s (range 0.34-0.85 m^3/s) for Sanlando Spring, 0.24 m^3/s (range 0.18-0.31 m^3/s) for Palm Spring, and 0.42 m^3/s (range 0.34-0.51 m^3/s) for Starbuck Spring (Florida Department of Environmental Regulation 1983). During this study,

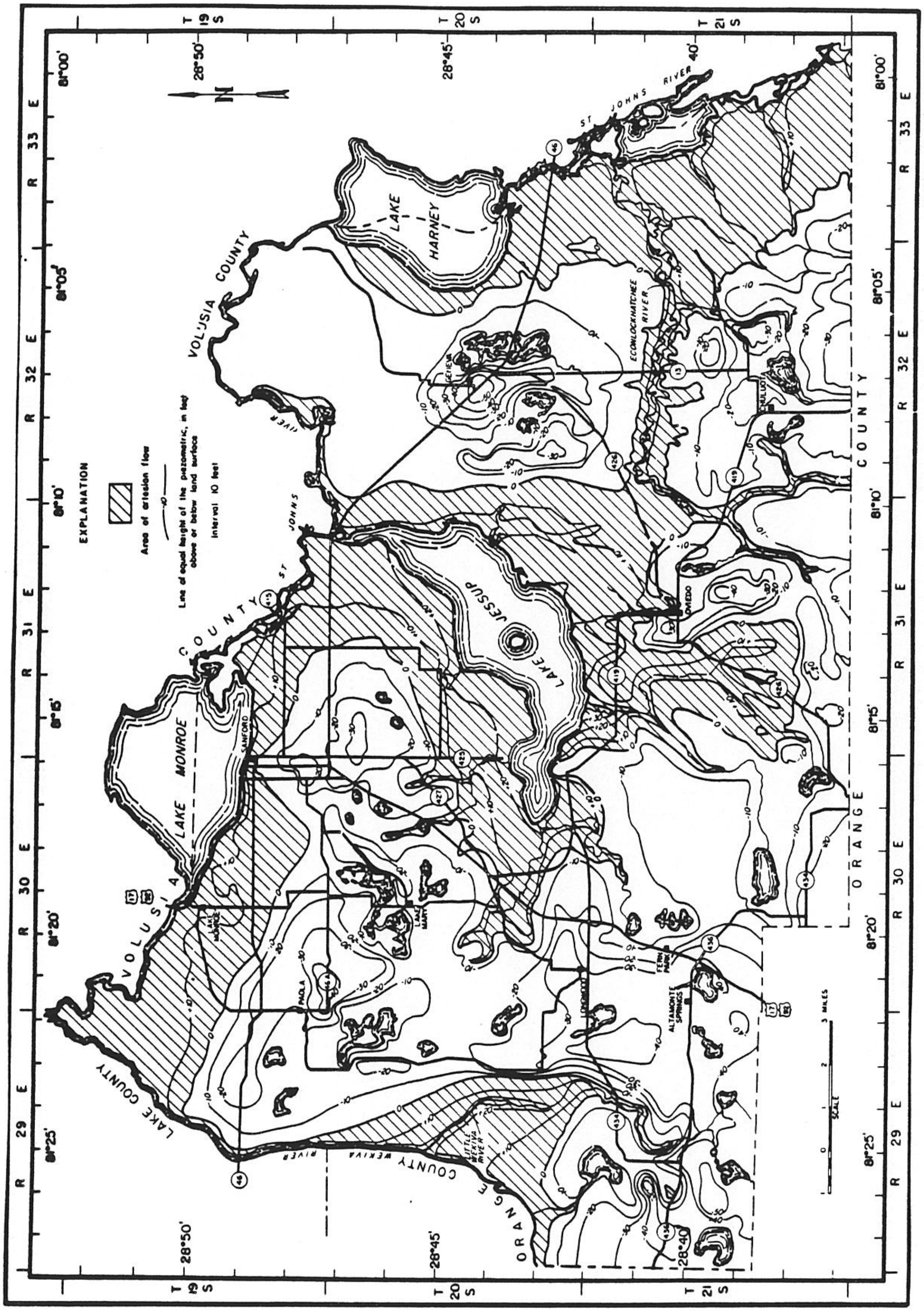


Figure 50. Map of artesian flow from Barraclough (1962).

our average instantaneous discharge measurements for Sanlando Spring and Palm Spring were lower than the 1974-1980 discharge measurements. This suggests that ground water levels in the upper Little Wekiva River basin may have been lowered enough over the last 30 years to permit the loss of flow through the stream channel from Station 6 to Station 12. Additional studies of the groundwater hydrology in the upper Little Wekiva River, however, are needed to determine if this hypothesis regarding recharge through the stream bottom is correct because we did not conduct any direct measurements of flow-loss through the channel and we measured a greater discharge from Starbuck Spring (Table 4) than earlier investigators.

Current Velocity

Although stream discharge, especially discharge during flood and drought events, has definite effects on the nature of streams, current velocity is generally a more important parameter for structuring the biology of a stream (Butcher 1933). The strength of the current determines not only the water residence time in any particular reach of stream but the general nature and stability of the stream bed, which strongly influences plant and animal communities (Leopold et al. 1964 and Hynes 1970). Streams with current velocities > 1 m/s typically have bottom substrates composed of either course gravel or rock. Vegetation is generally composed of mosses, filamentous algae, and algae attached to the bottom. Rooted aquatic macrophytes are sparse due to the lack of organic silt and insufficient substrate for rooting (Butcher 1933). Streams with current velocities < 1 m/s but greater than 0.6 m/s generally have stream beds composed of gravel or rock, but more organic silt is often present in the interstices (Butcher 1933). The vegetation is generally similar to that found in faster flowing streams, but plants possessing strong stems and small leaves (e.g., *Hydrilla verticillata* or *Myriophyllum* spp.) or roots capable of forming a lattice-work among the stones (e.g., *Potamogeton* spp.) generally become more common. Bottom substrates of sand typically dominate when current velocities are slow to moderate (> 0.20 m/s but < 0.50 m/s). If the bottom is composed of shifting sand, vegetation will be sparse until the stream bed can be consolidated by plant growth (Butcher 1933). The characteristic plants will have fibrous roots or matted rhizomes and a rapid growth that will enable them to quickly push through a covering layer of sand and silt (e.g., *Vallisneria americana* and *Panicum* spp.). Streams with current velocities < 0.20 m/s generally have silty-sand, silt, mud and alluvial bottom deposits. The vegetation is most often dominated by emergent (e.g., *Panicum* spp. and *Typha* spp.), floating-leaved (e.g., *Nuphar* spp.), and floating vegetation (e.g., *Hydrocotyle* spp., *Pistia* sp., *Eichhornia* sp.).

The Little Wekiva River has an average water residence time of < 2 days, which is similar to other small streams in Florida (Table 3). During the low flow periods of 1985, the aquatic vegetation in the Little Wekiva caused the river to flow through narrow channels, and the average water residence time was 0.5 day. In 1986, streamflow was greater (Table 4), but the average water residence time increased to 1 day due to an expansion in stream size (Table 3) and a restriction of flow by aquatic macrophytes. The ability of dense growths of aquatic macrophytes (2-4 kg fresh weight/m^2) to retard the flow of water and cause flooding in streams and rivers has been well documented (Butcher 1933; Dawson 1978; Kern-Hansen and Holm 1982; Westlake and Dawson 1982).

The upper Little Wekiva River had a stream gradient of 1.6 m/km. Mean current velocity between Lotus Lake and Station 3 averaged < 0.10 m/s, and most of the stream bed was composed of silt and mud (Table 5). Below Station 3, the slope of the stream bed increased and the volume of water carried by the stream increased significantly due to anthropogenic inputs. Mean current velocities at our sampling stations below Station 3 generally exceeded 0.20 m/s during 1985 and 1986 (Table 5). Maximum current velocities in the upper Little Wekiva River exceeded 0.40 m/s. These current velocities are above the critical value (see Leopold et al. 1964) required to initiate the movement of sand along the stream bed. Consequently, the upper Little Wekiva River experienced erosion along its banks, had a bottom of shifting sand, and supported very little aquatic vegetation in the stream channel during the study.

The lower Little Wekiva River had a stream gradient of 0.26 m/km and a lower mean current velocity than the upper Little Wekiva River (Table 5). The average current velocity between Starbuck Spring and Station 17, however, exceeded 0.25 m/s in 1985 and 1986. Massive paragrass beds constricted streamflow

Table 5. Mean, minimum, and maximum current velocity (V) for major point source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	V (m/s) Mean		Minimum	Maximum
2	1985	0.06	(± 0.04)	0.02	0.21
3	1985	0.16	(± 0.09)	0.05	0.36
	1986	0.20	(± 0.09)	0.07	0.29
Altamonte Springs STP	1985	0.22	(± 0.05)	0.11	0.32
	1986	0.11	(± 0.05)	0.05	0.16
6	1985	0.37	(± 0.13)	0.14	0.82
	1986	0.45	(± 0.27)	0.24	0.78
Weathersfield STP	1985	0.05	(± 0.02)	0.02	0.12
	1986	0.03	(± 0.01)	0.02	0.04
8	1985	0.27	(± 0.06)	0.17	0.46
Hi-Acres	1985	0.66	(± 0.17)	0.32	1.05
	1986	0.54	(± 0.09)	0.48	0.60
10	1985	0.29	(± 0.07)	0.18	0.54
	1986	0.37	(± 0.28)	0.08	0.73
11	1985	0.37	(± 0.11)	0.23	0.72
12	1985	0.22	(± 0.06)	0.10	0.42
	1986	0.32	(± 0.07)	0.20	0.65
Sanlando (13.1) Springs	1985	0.31	(± 0.11)	0.12	0.73
	1986	0.22	(± 0.11)	0.09	0.34
(13.3)	1985	0.25	(± 0.10)	0.04	0.58
	1986	0.45	(± 0.28)	0.27	0.90
Palm Spring	1985	0.16	(± 0.04)	0.05	0.26
	1986	0.11	(± 0.03)	0.07	0.13
Starbuck Spring	1985	0.10	(± 0.02)	0.06	0.17
	1986	0.21	(± 0.03)	0.18	0.25
14	1985	0.37	(± 0.07)	0.23	0.51
15	1985	0.34	(± 0.05)	0.24	0.48

Table 5. Continued

Station	Year	V (m/s) Mean		Minimum	Maximum
16	1985	0.28	(± 0.04)	0.20	0.39
	1986	0.31	(± 0.13)	0.19	0.44
17	1985	0.18	(± 0.04)	0.11	0.27
	1986	0.29	(± 0.09)	0.19	0.37
18	1985	0.17	(± 0.03)	0.08	0.23
19	1985	0.16	(± 0.04)	0.08	0.28
20	1985	0.14	(± 0.02)	0.08	0.20
21	1985	0.19	(± 0.03)	0.12	0.29
	1986	0.22	(± 0.05)	0.17	0.26
22	1985	0.23	(± 0.02)	0.18	0.28
23	1985	0.17	(± 0.03)	0.10	0.26
24	1985	0.19	(± 0.03)	0.15	0.28
25	1985	0.18	(± 0.02)	0.13	0.27
	1986	0.22	(± 0.05)	0.17	0.28

into narrow channels, which significantly increased current velocities. The bottom substrates of these narrow channels were composed of shifting sand and hard clay. Current velocities just inside the edge of the paragrass beds, however, were typically < 0.1 m/s, and the bottom sediments were silt and mud. The average current velocity at Station 17 was 0.18 m/s in 1985 (Table 5). By 1986, Station 17 was significantly shallower due to the downstream movement of large amounts of sand, and the mean current velocity was 0.29 m/s. Below Station 17, mean current velocities at our sampling stations were < 0.25 m/s, and most reaches of the stream had bottom deposits of silty-sand, silt, and mud. Current velocities between Station 14 and Station 25 averaged 0.22 m/s and were similar to the average current velocities measured in other streams sampled during this study (Table 6).

WATER QUALITY

The water quality of the Little Wekiva River has been influenced by point-source discharges and stormwater runoff for over 30 years. Prior to 1977, seven sewage treatment plants and the Hi-Acres Citrus processing plant discharged their effluents to the upper Little Wekiva River, which caused the stream to experience severe water quality problems (Florida Department of Environmental Regulation 1983). Since 1977, water quality in the upper Little Wekiva River has changed because most of the point-

Table 6. Mean, minimum, and maximum current velocity (V) measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	V(m/s)			
	Mean		Minimum	Maximum
Little Wekiva	0.22	(± 0.01)	0.07	0.50
Alexander Springs	0.20	(± 0.05)	0.04	0.35
Ichetucknee River	0.35	(± 0.07)	0.11	0.66
Alligator Creek	0.22	(± 0.07)	0.03	0.54
Rock Springs Run	0.28	(± 0.07)	0.02	0.63
Little Econlockhatchee	0.22	(± 0.07)	0.01	0.54
Wacissa River	0.24	(± 0.06)	0.10	0.57
Wekiva River	0.20	(± 0.02)	0.06	0.41
Alafia River	0.50	(± 0.12)	0.10	1.50
Reedy Creek	0.15	(± 0.05)	0	0.33
Pottsburg Creek	0.13	(± 0.05)	0.05	0.26
Mills Creek	0.10	(± 0.05)	0	0.26
St. Marks River	0.27	(± 0.10)	0.07	0.62
Econlockhatchee	0.31	(± 0.15)	0.04	0.98
Hillsborough River	0.12	(± 0.05)	0.01	0.24
Hogtown Creek	0.30	(± 0.04)	0.21	0.49
Upper Santa Fe River	0.21	(± 0.09)	0.02	0.50

source discharges have been removed and enhanced treatment has improved the quality of their effluent (Florida Department of Environmental Regulation 1983). The Altamonte Springs Regional Wastewater Treatment Plant, the largest contributor of treated wastewater, is currently being expanded to handle an increased volume of wastewater and upgraded to further improve the quality of its effluent (HNTB 1985). Water quality in the stream, however, is still significantly influenced by point-source discharges and stormwater runoff.

Temperature

The Little Wekiva River is a warm-water stream like other Florida streams (Table 7; Bass and Cox 1985). Water temperatures tend to parallel both seasonal and daily air temperatures (mean annual temperature 22 $^{\circ}C$) but are moderated in the upper and lower Little Wekiva River by inputs of treated wastewater from the Altamonte Springs Regional Wastewater Treatment Plant, cooling water from the Hi-Acres Citrus processing plant, and spring-water from Sanlando Spring, Palm Spring, and Starbuck Spring (Table 8). There is an especially pronounced warming of the stream during winter months when streamflow is low. Average water temperatures in the river, however, varied significantly between sampling stations during 1985. The upper Little Wekiva River received water from Lotus Lake that had an average temperature of 25 $^{\circ}C$ (Table 8). Because streamflow was reduced during most of 1985 and the reach of stream between Lotus Lake and Station 3 was generally well shaded, water temperatures in

Table 7. Mean, minimum, and maximum water temperature measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	Temperature (C) Mean	Minimum	Maximum
Little Wekiva	23 (± 1)	17	27
Alexander Springs	21 (± 1)	16	26
Ichetucknee River	20 (± 1)	19	21
Alligator Creek	22 (± 3)	15	28
Rock Springs Run	22 (± 2)	13	29
Little Econlockhatchee	21 (± 3)	8	28
Wacissa River	18 (± 2)	12	23
Wekiva River	21 (± 1)	18	26
Alafia River	19 (± 3)	12	27
Reedy Creek	17 (± 4)	4	27
Pottsburg Creek	18 (± 4)	9	28
Mills Creek	16 (± 4)	8	23
St. Marks River	17 (± 2)	13	20
Econlockhatchee	17 (± 12)	6	26
Hillsborough River	17 (± 6)	11	24
Hogtown Creek	15 (± 4)	5	23
Upper Santa Fe River	18 (± 3)	12	24

Table 8. Mean, minimum, and maximum temperatures measured at major point source dischares and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Temperature(C) Mean	Minimum	Maximum
Lotus Lake	1985	25 (± 3)	20	30
	1986	21 (± 6)	16	26
2	1985	21 (± 4)	13	29
3	1985	19 (± 4)	12	28
	1986	21 (± 4)	16	27
Altamonte Springs STP	1985	26 (± 2)	22	29
	1986	25 (± 3)	21	28
6	1985	24 (± 2)	20	28
	1986	22 (± 4)	18	26
Weathersfield STP	1985	23 (± 3)	15	31
	1986	22 (± 4)	17	27
8	1985	25 (± 2)	20	29
Hi-Acres	1985	27 (± 1)	23	29
	1986	25 (± 3)	23	27
10	1985	26 (± 1)	22	28
	1986	23 (± 4)	18	27
11	1985	25 (± 2)	21	29
12	1985	25 (± 2)	21	28
	1986	22 (± 4)	18	26
Sanlando (13.1) Springs	1985	24 (± 1)	22	25
	1986	22 (± 1)	21	22
(13.3)	1985	24 (± 1)	22	25
	1986	22 (± 1)	21	22
Palm Springs	1985	24 (± 1)	23	25
	1986	22 (± 1)	21	22
Starbuck Springs	1985	24 (± 1)	23	25
	1986	22 (± 1)	22	23

Table 8. Continued

Station	Temperature (C)			
	Year	Mean	Minimum	Maximum
14	1985	25 (± 1)	23	27
15	1985	24 (± 1)	21	27
16	1985	24 (± 1)	21	27
	1986	22 (± 2)	19	24
17	1985	24 (± 1)	20	27
	1986	22 (± 2)	20	25
18	1985	23 (± 1)	20	26
19	1985	23 (± 2)	19	27
20	1985	23 (± 2)	18	26
21	1985	22 (± 2)	18	26
	1986	21 (± 3)	18	24
22	1985	22 (± 2)	18	26
23	1985	22 (± 2)	17	26
24	1985	22 (± 2)	17	26
25	1985	21 (± 2)	17	26
	1986	21 (± 3)	19	2

the stream cooled, averaging 19 ^{o}C at Station 3. The addition of water from the Altamonte Springs Regional Wastewater Treatment Plant (average 26 ^{o}C) and the Hi-Acres Citrus processing plant (average 27 ^{o}C) caused stream water temperatures to increase significantly to an average of about 25 ^{o}C between Station 6 and Sanlando Spring (Table 8). Although water temperatures were elevated, the maximum measured temperatures in the effluents and the upper Little Wekiva River downstream of the point-source discharges never exceeded maximum values (32 ^{o}C to 36 ^{o}C) typically measured in Florida lakes (Canfield 1981) or critical values recommended for warm-water fish (Federal Water Pollution Control Administration 1968). During cold weather, the elevated stream temperatures may even benefit some aquatic species by providing a thermal refuge.

The water temperatures at Sanlando Spring, Palm Spring, and Starbuck Spring averaged 24 ^{o}C in 1985; thus, the addition of the spring-water reduced stream water temperatures only slightly (Table 8). There was, however, a significant reduction in average water temperature below Station 18 as the Little Wekiva River flowed through well shaded areas. The average water temperature at Station 25 during 1985 was 21 ^{o}C (Table 8). During 1986, stream water temperatures averaged 21 ^{o}C to 22 ^{o}C along the entire length of the Little Wekiva River, and warm-water inputs from the Altamonte Springs Regional Wastewater Treatment Plant and the Hi-Acres Citrus processing plant had little influence on stream temperatures. This was largely due to the fact that streamflows were higher in 1986.

Oxygen

The maintenance of a diversified warm-water biota in streams requires that dissolved oxygen levels remain adequate for survival. Consequently, it is generally recommended that daily dissolved oxygen concentrations remain above 5 mg/L (Federal Water Pollution Control Administration 1968). Many Florida streams, however, receive large amounts of anaerobic or nearly anaerobic groundwater, spring-water, or surface water runoff from swamps and wetlands and dissolved oxygen concentrations < 5 mg/L can be measured in just about all streams (Beck 1965; Bass and Cox 1985; Table 9). Dissolved oxygen concentrations < 5 mg/L were often measured in the Little Wekiva River during 1985 and 1986 (Table 10), and there were days when daily dissolved oxygen concentrations did not exceed 5 mg/L at some of our sampling stations (Table 11). Although the effects of these low oxygen discharges on the oxygen regime of a stream can be considerable, Beck (1965) noted that these discharges do not generally cause a total faunal alteration in Florida streams, and sport fish have been observed in a number of springs when dissolved oxygen concentrations were < 1.5 mg/L.

Dissolved oxygen concentrations varied significantly along the length of the Little Wekiva River during 1985 and 1986 in response to nonpoint source discharges, anthropogenic discharges, and discharges from Sanlando Spring, Palm Spring, and Starbuck Spring (Table 10). Dissolved oxygen concentrations averaged above 6 mg/L in Lotus Lake but averaged < 4 mg/L at Station 2 and

Table 9. Mean, minmum, and maximum dissolved oxygen (DO) concentrations measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

	DO (mg/L)		
Stream	Mean	Minimum	Maximum
Little Wekiva	5.9 (± 0.4)	2.3	8.9
Alexander Springs	6.5 (± 0.6)	3.5	8.2
Ichetucknee River	4.5 (± 0.5)	3.6	6.5
Alligator Creek	7.2 (± 0.9)	3.4	9.5
Rock Springs Run	7.1 (± 0.8)	3.2	10
Little Econlockhatchee	6.0 (± 0.8)	3.5	9.9
Wacissa River	7.4 (± 0.4)	6.3	8.5
Wekiva River	6.3 (± 0.7)	3.8	12
Alafia River	7.6 (± 0.8)	5.2	11
Reedy Creek	4.4 (± 1.1)	1.3	8.2
Pottsburg Creek	6.6 (± 1.3)	3.9	9.2
Mills Creek	4.4 (± 1.3)	1.8	8.0
St. Marks River	6.4 (± 0.6)	5.0	7.8
Econlockhatchee	7.4 (± 1.4)	4.3	11
Hillsborough River	5.2 (± 1.1)	1.8	7.3
Hogtown Creek	9.1 (± 1.1)	7.0	12
Upper Santa Fe River	6.5 (± 0.6)	5.3	8.6

Table 10. Mean, minimum, and maximum dissolved oxygen (DO) concentrations for major point source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	DO (mg/L)		
		Mean	Minimum	Maximum
Lotus Lake	1985	7.3 (± 0.7)	5.8	8.6
	1986	6.1 (± 0.7)	5.5	6.7
2	1985	3.6 (± 1.2)	1.8	6.6
3	1985	2.0 (± 1.0)	0.7	5.0
	1986	1.9 (± 1.4)	0.8	3.7
Altamonte Springs STP	1985	7.9 (± 0.3)	7.2	8.8
	1986	7.2 (± 0.8)	6.4	8.2
6	1985	5.9 (± 1.1)	2.9	7.7
	1986	4.4 (± 1.3)	2.9	5.5
Weathersfield STP	1985	7.6 (± 1.0)	4.7	10.2
	1986	7.2 (± 3.2)	4.8	11.9
8	1985	5.8 (± 1.2)	3.4	8.5
Hi-Acres	1985	7.7 (± 0.3)	7.0	8.7
	1986	7.7 (± 0.3)	7.5	7.9
10	1985	6.2 (± 1.0)	3.5	7.8
	1986	5.0 (± 1.2)	3.6	6.3
11	1985	6.7 (± 0.8)	4.9	8.4
12	1985	7.0 (± 0.6)	4.9	8.2
	1986	5.9 (± 0.9)	5.3	7.2
Sanlando (13.1) Spring	1985	3.7 (± 0.6)	1.6	4.9
	1986	3.3 (± 0.6)	2.5	3.8
(13.3)	1985	4.6 (± 1.1)	3.0	7.8
	1986	4.0 (± 1.1)	2.7	5.2
Palm Spring	1985	1.2 (± 0.4)	0.6	2.7
	1986	1.0 (± 0.5)	0.6	1.7
Starbuck Spring	1985	3.3 (± 1.3)	0.8	6.5
	1986	1.1 (± 0.3)	0.8	1.4

Table 10. Continued

Station	Year	DO (mg/L) Mean	Minimum	Maximum
14	1985	5.4 (± 0.9)	2.3	6.4
15	1985	6.1 (± 1.2)	3.0	8.4
16	1985	6.1 (± 1.1)	3.4	8.5
	1986	4.6 (± 1.3)	3.5	5.9
17	1985	6.7 (± 1.1)	3.9	8.9
	1986	4.9 (± 1.5)	3.5	6.7
18	1985	6.8 (± 1.1)	4.0	8.0
19	1985	6.1 (± 1.0)	3.7	8.0
20	1985	5.2 (± 1.0)	3.3	7.0
21	1985	5.5 (± 0.8)	3.3	7.2
	1986	4.7 (± 1.6)	2.8	6.1
22	1985	6.2 (± 0.9)	3.8	7.5
23	1985	5.8 (± 0.9)	3.6	7.4
24	1985	5.7 (± 0.9)	3.4	7.6
25	1985	5.5 (± 0.8)	3.2	7.2
	1986	5.0 (± 1.8)	3.1	7.0

Table 11. Dissolved oxygen concentrations (DO) and water temperatures in the Little Wekiva River at Station 17 on March 26, 1985.

Time	DO (mg/L)	Temperature (°C)
1300	4.2	23.0
1400	4.0	23.0
1500	3.6	23.0
1600	3.3	22.5
1700	3.1	22.0
1800	2.9	21.5
1900	2.8	21.0
2000	2.7	21.0
2100	2.6	20.5
2200	2.6	20.0
2300	2.6	20.0
2400	2.6	20.0
100	2.6	20.0
200	2.6	19.5
300	2.7	19.5
400	2.7	19.5
500	2.7	19.0
600	2.7	19.0
700	2.8	19.0
800	3.0	19.0
900	3.2	19.5
1000	3.5	20.0
1100	3.7	20.5
1200	3.9	21.0

Station 3 (Table 10). Oxygen levels in the upper Little Wekiva River declined primarily because the stream flowed slowly through very swampy land and Trout Lake, which is now a remnant lake filled with aquatic vegetation and trees. During 1985, stream dissolved oxygen concentrations below Station 3 were increased above 5 mg/L due to reaeration and the discharge of oxygen-rich waters from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant and the Hi-Acres Citrus processing plant (Table 10). Oxygen concentrations averaged 7.0 mg/L at Station 12 during 1985. Below Station 12, inputs of low-oxygen water from Sanlando Spring (4 mg/L), Palm Spring (1.2 mg/L) and Starbuck Spring (3.3 mg/L) caused stream dissolved oxygen concentrations to decline at Station 14 (Table 10). Dissolved oxygen concentrations, however, averaged over 6 mg/L between Station 15 and 19 due to the growth of aquatic plants in the stream. Dissolved oxygen concentrations averaged < 6 mg/L below Station 22 and averaged only 5.5 mg/L at the river's confluence with the Wekiva River. During 1986, stream dissolved oxygen concentrations averaged $\leq$ 5 mg/L at all sampling stations except Station 12, where dissolved oxygen concentrations averaged 5.9 mg/L (Table 10). The lower average dissolved oxygen concentrations measured during 1986 were primarily caused by the increased flow of low-oxygen water from stormwater runoff.

The discharge of raw organic wastes or inadequately treated wastes can significantly reduce stream dissolved oxygen concentrations due to the high biochemical oxygen demand (BOD) of the wastes. BOD levels in the Little Wekiva River have been reduced significantly since 1977 because of improved wastewater treatment and the discharge of cooling water from the Hi-Acres Citrus processing plant (Florida Department of Environmental Regulation 1983). Although materials with some BOD are still discharged from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant, these effluents were not the cause of the low dissolved oxygen concentrations measured in the Little Wekiva River during 1985 and 1986 (also see McClelland 1982). Dissolved oxygen concentrations in the effluents averaged > 7 mg/L (Table 10) and generally caused downstream dissolved oxygen concentrations to increase. We also did never measured an oxygen sag downstream of the Altamonte Springs Regional Sewage Plant, suggesting BOD loads were not very large. We did measure oxygen concentrations < 5 mg/L at the Weathersfield Sewage Treatment Plant on a couple of occasions (Table 10), but these reductions in oxygen concentrations had no effect on stream oxygen concentrations due to the treatment plant's low volume of discharge. The Weathersfield Sewage Treatment Plant utilizes treatment ponds, and after several days of very cloudy weather, there can be a temporary lowering of dissolved oxygen concentrations due to algal respiration and/or the collapse of the algal population in the final treatment pond.

Oxygen concentrations in the Little Wekiva River were affected by low-oxygen discharges from Trout Lake, Sanlando Spring, Palm Spring, and Starbuck Spring (Table 10). During 1985 and 1986, dissolved oxygen concentrations in the water exiting

Trout Lake averaged ≤ 2 mg/L, and oxygen levels < 1 mg/L were measured. At Sanlando Spring, dissolved oxygen concentrations averaged < 5 mg/L, and we measured oxygen concentrations ≤ 3 mg/L. Oxygen concentrations in the water leaving Sanlando Spring via Station 13.3 were often higher than concentrations in the water leaving Station 13.1, but this was due primarily to the growth of large amounts of hydrilla in the discharge channel. Oxygen concentrations in the water leaving Palm Spring and Starbuck Spring generally averaged < 2 mg/L. Starbuck Spring had an average dissolved oxygen concentration of 3.3 mg/L in 1985, but the spring supported more aquatic plants during 1985 than 1986. In both of these springs, we measured oxygen concentrations < 1 mg/L on different sampling days.

pH and Total Alkalinity

The Little Wekiva River is best described as an alkaline, highly buffered stream, which is typical of many of Florida's spring-fed streams (Beck 1965; Tables 12 and 13). Waters in the upper Little Wekiva River between Lotus Lake and the Altamonte Springs Regional Wastewater Treatment Plant, however, were mildly acidic (pH 6.9) and had an average total alkalinity ≤ 50 mg/L as $CaCO_3$ during 1985 and 1986 (Tables 14 and 15). Stream pH and total alkalinity values were elevated with the addition of waters from the Altamonte Springs Regional Wastewater Treatment Plant (pH 7.7; total alkalinity 105 mg/L as $CaCO_3$), the Weathersfield Sewage Treatment Plant (pH 7.6; total alkalinity 144 mg/L as $CaCO_3$), and the Hi-Acres Citrus processing plant (pH 8.0; total

Table 12. Mean, minimum, and maximum pH values measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limit.

	pH		
Stream	Mean	Minimum	Maximum
Little Wekiva	7.7 (± 0.1)	7.1	8.0
Alexander Springs	7.5 (± 0.1)	7.1	7.8
Ichetucknee River	7.9 (± 0.1)	7.7	8.0
Alligator Creek	7.1 (± 0.1)	6.8	7.6
Rock Springs Run	7.6 (± 0.2)	7.0	8.5
Little Econlockhatchee	7.0 (± 0.1)	6.6	7.4
Wacissa River	7.9 (± 0.1)	7.5	8.5
Wekiva River	7.7 (± 0.1)	7.1	8.8
Alafia River	7.6 (± 0.1)	7.2	7.8
Reedy Creek	6.5 (± 0.2)	6.0	7.5
Pottsburg Creek	7.4 (± 0.1)	7.1	7.7
Mills Creek	6.6 (± 0.1)	6.4	6.8
St. Marks River	7.7 (± 0.2)	7.4	8.0
Econlockhatchee	6.9 (± 0.2)	6.7	7.6
Hillsborough River	7.4 (± 0.2)	7.2	7.9
Hogtown Creek	7.8 (± 0.1)	7.5	7.9
Upper Santa Fe River	6.8 (± 0.3)	5.8	7.4

Table 13. Mean, minimum, and maximum total alkalinity values measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

	Total Alkalinity (mg/L as $CaCO_3$)		
Stream	Mean	Minimum	Maximum
Little Wekiva	101 (± 2)	67	114
Alexander Springs	68 (± 5)	53	81
Ichetucknee River	140 (± 1)	137	143
Alligator Creek	25 (± 6)	11	53
Rock Springs Run	80 (± 4)	62	89
Little Econlockhatchee	36 (± 4)	17	54
Wacissa River	124 (± 5)	92	134
Wekiva River	91 (± 3)	69	101
Alafia River	59 (± 6)	38	85
Reedy Creek	30 (± 8)	10	61
Pottsburg Creek	74 (± 9)	43	95
Mills Creek	24 (± 4)	16	45
St. Marks River	95 (± 14)	68	120
Econlockhatchee	32 (± 16)	18	90
Hillsborough River	95 (± 20)	61	139
Hogtown Creek	82 (± 8)	57	102
Upper Santa Fe River	24 (± 9)	6	44

Table 14. Mean, minimum, and maximum pH major point source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		pH		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	7.3 (± 0.3)	6.4	7.6
	1986	7.3 (± 0.3)	7.2	7.5
2	1985	6.9 (± 0.2)	6.3	7.2
3	1985	6.7 (± 0.2)	6.2	7.0
	1986	6.9 (± 0.2)	6.6	7.0
Altamonte Springs STP	1985	7.7 (± 0.2)	7.3	8.0
	1986	7.7 (± 0.3)	7.4	8.2
6	1985	7.3 (± 0.2)	6.8	7.5
	1986	7.2 (± 0.3)	7.1	7.6
Weathersfield STP	1985	7.6 (± 0.2)	7.3	8.0
	1986	7.6 (± 0.2)	7.4	7.8
8	1985	7.4 (± 0.2)	6.8	7.5
Hi-Acres	1985	8.0 (± 0.2)	7.7	8.2
	1986	8.0 (± 0.0)	8.0	8.0
10	1985	7.5 (± 0.3)	7.1	7.7
	1986	7.4 (± 0.2)	7.2	7.6
11	1985	7.6 (± 0.2)	7.1	7.8
12	1985	7.6 (± 0.2)	7.1	8.0
	1986	7.4 (± 0.2)	7.2	7.5
Sanlando Spring (13.1)	1985	7.6 (± 0.2)	7.0	7.8
	1986	7.6 (± 0.1)	7.5	7.6
(13.3)	1985	7.6 (± 0.3)	7.1	7.9
	1986	7.6 (± 0.1)	7.5	7.7
Palm Spring	1985	7.6 (± 0.2)	7.1	7.8
	1986	7.6 (± 0.1)	7.5	7.6
Starbuck Spring	1985	7.7 (± 0.1)	7.4	8.0
	1986	7.7 (± 0.1)	7.5	7.7

Table 14. Continued

Station	Year	pH Mean	pH Minimum	pH Maximum
14	1985	7.7 (± 0.2)	7.3	7.9
15	1985	7.7 (± 0.2)	7.3	7.9
16	1985	7.7 (± 0.2)	7.3	8.0
	1986	7.6 (± 0.1)	7.5	7.6
17	1985	7.7 (± 0.2)	7.4	8.0
	1986	7.6 (± 0.1)	7.5	7.7
18	1985	7.7 (± 0.2)	7.3	8.0
19	1985	7.7 (± 0.2)	7.1	8.0
20	1985	7.6 (± 0.1)	7.2	7.8
21	1985	7.6 (± 0.1)	7.2	7.8
	1986	7.5 (± 0.2)	7.3	7.6
22	1985	7.7 (± 0.2)	7.3	7.9
23	1985	7.7 (± 0.2)	7.3	7.9
24	1985	7.7 (± 0.2)	7.3	7.9
25	1985	7.7 (± 0.2)	7.3	8.0
	1986	7.5 (± 0.2)	7.2	7.6

Table 15. Mean, minimum, and maximum total alkalinity concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Total Alkalinity (mg/L as $CaCO_3$)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	48 (± 7)	37	64
	1986	42 (± 7)	37	46
2	1985	49 (± 6)	37	65
3	1985	50 (± 7)	36	70
	1986	47 (± 11)	39	62
Altamonte Springs STP	1985	100 (± 6)	87	117
	1986	111 (± 29)	88	154
6	1985	79 (± 10)	49	106
	1986	72 (± 27)	50	109
Weathersfield STP	1985	138 (± 5)	124	146
	1986	150 (± 16)	131	166
8	1985	80 (± 11)	50	105
Hi-Acres	1985	108 (± 3)	96	112
	1986	110 (± 3)	109	111
10	1985	88 (± 11)	57	106
	1986	79 (± 28)	52	115
11	1985	86 (± 11)	50	102
12	1985	85 (± 9)	57	101
	1986	73 (± 19)	51	91
Sanlando (13.1) Spring	1985	122 (± 2)	116	126
	1986	125 (± 3)	121	127
(13.3)	1985	121 (± 2)	117	126
	1986	124 (± 4)	118	127
Palm Spring	1985	112 (± 1)	108	115
	1986	113 (± 2)	111	114
Starbuck Spring	1985	113 (± 1)	110	115
	1986	113 (± 3)	110	116

Table 15 (Cont.).

Station	Year	Total Alkalinity (mg/L as $CaCO_3$) Mean	Minimum	Maximum
14	1985	100 (± 7)	75	109
15	1985	102 (± 8)	76	110
16	1985	103 (± 7)	77	111
	1986	95 (± 17)	72	108
17	1985	101 (± 7)	77	110
	1986	94 (± 16)	72	107
18	1985	103 (± 8)	77	111
19	1985	102 (± 7)	78	109
20	1985	102 (± 7)	78	113
21	1985	103 (± 7)	79	114
	1986	92 (± 18)	69	107
22	1985	102 (± 7)	78	112
23	1985	102 (± 8)	76	111
24	1985	102 (± 8)	76	111
25	1985	102 (± 8)	76	112
	1986	91 (± 18)	67	106

alkalinity 109 mg/L as $CaCO_3$). Between Station 10 and Station 12, stream pH values were virtually identical to values measured in the lower Little Wekiva River (Table 14), but total alkalinity values were lower (Table 15). Following the addition of spring-water from Sanlando Spring (pH 7.6; total alkalinity 124 mg/L as $CaCO_3$), Palm Spring (pH 7.6; total alkalinity 112 mg/L as $CaCO_3$) and Starbuck Spring (pH 7.7; total alkalinity 113 mg/L as $CaCO_3$), there was no significant change in the pH or total alkalinity values measured between Station 14 and Station 25 (Tables 14 and 15).

Although the Little Wekiva River and other spring-fed streams are well buffered, changes in stream pH and total alkalinity values occur (Tables 12, 13, 14, and 15). During periods of dry weather, stream pH and total alkalinity values increase reflecting the greater contribution of groundwater. For example, total alkalinity values in the lower Little Wekiva River averaged above 100 mg/L as $CaCO_3$ during 1985 when discharge was reduced (Table 15). During periods of wet weather, pH and total alkalinity values are reduced due to the greater input of surface runoff. In the lower Little Wekiva River, total alkalinity values < 80 mg/L as $CaCO_3$ were measured during periods of high discharge, and lower average values were measured at all sampling stations during 1986 (Table 15).

Salinity

The total salinity of inland waters is usually dominated completely by four major cations - calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) - and the major anions - carbonate (CO_3), sulfate (SO_4), and chloride (Wetzel 1975). Salinity in pristine waters is governed by the lithology of the stream basin, atmospheric precipitation, and balances between evaporation and precipitation. Discharges from anthropogenic sources can, however, significantly alter the total salinity of a water body if there is insufficient dilution capacity.

The total salinity of Florida's freshwater streams is seldom measured on a regular basis, but specific conductance is routinely measured because specific conductance is proportional to the concentration of major ions (dissolved solids) in the stream. The specific conductance of water in Florida streams typically ranges from < 200 µS/cm @ 25 °C to over 1500 µS/cm @ 25 °C (Slack and Kaufman 1975; Table 16). Specific conductance values within a single stream are generally inversely related to streamflow (Slack and Kaufman 1975). Low specific conductance values in a stream during high flow reflect a dilution of streamflow derived from groundwater sources by storm runoff that is relatively free of dissolved solids.

The waters of Lotus Lake and the upper Little Wekiva River prior to the discharge of the Altamonte Springs Regional Wastewater Treatment Plant had an average specific conductance of 190 µS/cm @ 25 °C during 1985 and 1986 (Table 17). Maximum

Table 16. Mean, minimum, and maximum specific conductance values measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limit.

Stream	Specific Conductance (µS/cm @ 25 oC)		
	Mean	Minimum	Maximum
Little Wekiva	301 (± 4)	223	343
Alexander Springs	939 (± 46)	779	1102
Ichetucknee River	299 (± 3)	286	307
Alligator Creek	296 (± 35)	207	401
Rock Springs Run	309 (± 29)	230	416
Little Econlockhatchee	285 (± 81)	103	978
Wacissa River	257 (± 10)	198	275
Wekiva River	422 (± 61)	265	790
Alafia River	427 (± 37)	294	559
Reedy Creek	163 (± 35)	85	322
Pottsburg Creek	5140 (± 4100)	227	19000
Mills Creek	475 (± 405)	107	2300
St. Marks River	210 (± 29)	158	260
Econlockhatchee	216 (± 30)	160	488
Hillsborough River	259 (± 42)	167	338
Hogtown Creek	221 (± 18)	160	274
Upper Santa Fe River	124 (± 19)	83	175

Table 17. Mean, minimum, and maximum specific conductance values for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Specific Conductance (µS/cm @ 25 °C)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	184 (± 21)	148	219
	1986	171 (± 22)	148	185
2	1985	192 (± 18)	152	229
3	1985	202 (± 19)	154	239
	1986	186 (± 28)	152	210
Altamonte Springs STP	1985	498 (± 16)	453	551
	1986	517 (± 123)	437	696
6	1985	399 (± 61)	224	497
	1986	303 (± 100)	196	396
Weathersfield STP	1985	523 (± 27)	437	583
	1986	543 (± 31)	520	582
8	1985	402 (± 68)	215	495
Hi-Acres	1985	237 (± 6)	227	260
	1986	238 (± 9)	235	245
10	1985	340 (± 47)	210	419
	1986	294 (± 93)	198	408
11	1985	322 (± 45)	182	406
12	1985	308 (± 35)	218	395
	1986	202 (± 93)	178	345
Sanlando (13.1) Spring	1985	290 (± 6)	276	302
	1986	302 (± 8)	295	312
(13.3)	1985	291 (± 5)	281	307
	1986	300 (± 12)	286	314
Palm Springs	1985	293 (± 7)	281	323
	1986	300 (± 6)	291	304
Starbuck Spring	1985	307 (± 6)	296	330
	1986	311 (± 5)	305	316

Table 17. Continued

Station	Year	Specific Conductance (µS/cm @ 25 °C) Mean	Minimum	Maximum
14	1985	299 (± 20)	232	326
15	1985	293 (± 19)	232	326
16	1985	294 (± 18)	232	328
	1986	284 (± 44)	229	323
17	1985	299 (± 16)	242	333
	1986	286 (± 46)	223	323
18	1985	300 (± 18)	244	328
19	1985	307 (± 20)	244	337
20	1985	307 (± 20)	244	343
21	1985	307 (± 16)	250	333
	1986	287 (± 49)	223	330
22	1985	306 (± 17)	255	340
23	1985	309 (± 14)	260	333
24	1985	308 (± 14)	260	333
25	1985	311 (± 13)	260	333
	1986	295 (± 39)	238	326

measured specific conductance values at our sampling stations never exceeded 250 µS/cm @ 25 °C. The Altamonte Springs Regional Wastewater Treatment Plant, however, discharged mineral-rich water (Table 17). During 1985 and 1986, the effluent had an average specific conductance close to 500 µS/cm @ 25 °C. Discharges from the plant caused average specific conductance values in the upper Little Wekiva River between Station 3 and Station 8, to double (average 400 µS/cm @ 25 °C) during 1985. Specific conductance in the river was also increased by discharges from the Altamonte Springs Regional Wastewater Treatment Plant (Station 4) during 1986, but the average increases were much less due to increased streamflow upstream of the plant. The Weathersfield Sewage Treatment Plant also contributed mineral-rich water (average specific conductance 530 µS/cm @ 25 °C) to the upper Little Wekiva River, but the low discharge from this facility precluded any significant impact on stream specific conductance values. Specific conductance values in the stream, however, were reduced below the discharge from the Hi-Acres Citrus processing plant (average specific conductance 238 µS/cm @ 25 °C) due to dilution by the cooling effluent (Table 17). Specific conductance at Station 12 averaged 308 µS/cm @ 25 °C during 1985 and 202 µS/cm @ 25 °C during 1986.

In the lower Little Wekiva River, the stream received major inputs of mineral-rich water from Sanlando Spring, Palm Spring, and Starbuck Spring (Table 17). The springs discharged water with an average specific conductance close to 300 µS/cm @ 25 °C. During 1985, specific conductance values between Station 14 and

Station 25 averaged about 300 µS/cm @ 25 ^{o}C, reflecting the importance of the spring discharges during low flow periods. Specific conductance values during 1986 averaged < 300 µS/cm @ 25 ^{o}C, reflecting the dilution of spring flow during high-flow periods. The discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus Plant did not appreciably affect the total salinity of the lower Little Wekiva River during 1985 and 1986 because the Hi-Acres Citrus processing plant effectively diluted the mineral-rich water discharged from the Altamonte Springs Regional Wastewater Treatment Plant and the Weathersfield Sewage Treatment Plant. Discharges from the Hi-Acres Citrus processing plant, however, have now ceased, and the influence of the wastewater treatment plants on the total salinity of the stream should become much more important, especially during low-flow periods, in both the upper and lower Little Wekiva River.

The chemical quality of surface water in Florida streams varies widely in composition and in concentration of major ions (Kaufman 1975). Calcium and magnesium concentrations in the Little Wekiva River during 1985 and 1986 were increased by discharges from the Altamonte Springs Regional Wastewater Treatment Plant, the Weathersfield Sewage Treatment Plant, and the Hi-Acres Citrus processing plant (Tables 18 and 19). Calcium concentrations in the upper Little Wekiva River averaged 17 mg/L during 1985 and 1986, and magnesium concentrations averaged slightly over 3 mg/L. The Altamonte Springs Regional Wastewater Treatment Plant and the Hi-Acres Citrus processing plant during

Table 18. Mean, minimum, and maximum calcium concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Calcium (mg/L) Mean	Minimum	Maximum
Lotus Lake	1985	16 (± 3)	9	20
	1986	17 (± 4)	13	19
2	1985	17 (± 2)	9	20
3	1985	17 (± 2)	9	21
	1986	18 (± 3)	16	23
Altamonte Spring STP	1985	30 (± 2)	22	36
	1986	30 (± 3)	26	32
6	1985	25 (± 3)	15	30
	1986	23 (± 5)	18	27
Weathersfield STP	1985	33 (± 3)	26	38
	1986	41 (± 2)	38	43
8	1985	26 (± 4)	16	32
Hi-Acres	1985	29 (± 1)	27	32
	1986	31 (± 1)	30	31
10	1985	27 (± 3)	17	31
	1986	24 (± 5)	19	28
11	1985	26 (± 3)	15	30
12	1985	26 (± 2)	17	30
	1986	24 (± 5)	19	30
Sanlando Spring (13.1)	1985	36 (± 1)	34	38
	1986	37 (± 4)	34	42
(13.3)	1985	36 (± 1)	34	38
	1986	37 (± 5)	34	44
Palm Spring	1985	34 (± 5)	11	38
	1986	36 (± 2)	34	39
Starbuck Spring	1985	36 (± 1)	34	38
	1986	36 (± 4)	34	42

Table 18(Cont.).

Station	Year	Calcium (mg/L) Mean	Minimum	Maximum
14	1985	31 (± 2)	24	34
15	1985	32 (± 2)	24	35
16	1985	32 (± 2)	24	36
	1986	31 (± 7)	24	39
17	1985	32 (± 2)	23	36
	1986	30 (± 5)	25	34
18	1985	32 (± 2)	24	36
19	1985	31 (± 3)	24	34
20	1985	31 (± 2)	24	34
21	1985	32 (± 2)	24	34
	1986	30 (± 5)	25	35
22	1985	32 (± 2)	24	34
23	1985	32 (± 2)	24	36
24	1985	32 (± 2)	24	34
25	1985	32 (± 2)	24	36
	1986	30 (± 5)	26	35

Table 19. Mean, minimum, and maximum magnesium concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Magnesium (mg/L)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	3.6 (± 0.5)	2.6	4.5
	1986	3.1 (± 0.5)	2.6	3.4
2	1985	3.7 (± 0.4)	2.6	4.4
3	1985	4.2 (± 0.5)	2.7	5.2
	1986	3.4 (± 0.6)	2.6	4.1
Altamonte Spring STP	1985	8.5 (± 0.3)	8.0	9.2
	1986	7.9 (± 0.5)	7.3	8.4
6	1985	6.9 (± 0.9)	3.9	8.4
	1986	5.1 (± 1.4)	3.5	6.3
Weathersfiled STP	1985	12 (± 0.2)	12	13
	1986	11 (± 1)	10	12
8	1985	6.6 (± 1.2)	4.0	8.4
Hi-Acres	1985	8.3 (± 0.3)	7.2	8.8
	1986	8.3 (± 0.8)	8.0	8.8
10	1985	6.9 (± 1.1)	4.0	8.4
	1986	5.4 (± 1.6)	3.5	7.2
11	1985	7.0 (± 1.0)	3.5	8.2
12	1985	6.9 (± 0.9)	4.3	8.4
	1986	5.4 (± 1.9)	3.2	7.7
Sandlando Spring (13.1)	1985	10 (± 0.3)	10	11
	1986	10 (± 1)	8.7	11
(13.3)	1985	10 (± 0.3)	10	11
	1986	9.8 (± 1.7)	7.3	11
Palm Spring	1985	11 (± 0.9)	7.2	12
	1986	11 (± 1)	9.7	11
Starbuck Spring	1985	10 (± 0.4)	10	12
	1986	9.3 (± 1.5)	7.0	10

Table 19. Continued

		Magnesium (mg/L)		
Station	Year	Mean	Minimum	Maximum
14	1985	8.9 (± 0.8)	6.1	10
15	1985	8.9 (± 0.9)	6.0	10
16	1985	8.7 (± 0.7)	6.3	9.6
	1986	5.8 (± 1.9)	5.8	9.7
17	1985	8.7 (± 0.7)	6.2	10
	1986	7.9 (± 2.4)	4.4	9.5
18	1985	8.9 (± 0.8)	6.5	10
19	1985	8.9 (± 0.9)	6.2	10
20	1985	9.0 (± 0.8)	6.3	10
21	1985	9.0 (± 0.7)	6.8	10
	1986	7.6 (± 2.4)	4.3	9.4
22	1985	9.0 (± 0.7)	6.8	10
23	1985	9.1 (± 0.7)	7.0	10
24	1985	9.2 (± 0.7)	6.8	10
25	1985	9.0 (± 0.6)	7.0	10
	1986	8.0 (± 2.3)	4.8	9.5

1985 and 1986 discharged water having an average calcium concentration of 30 mg/l and an average magnesium concentration of 8.3 mg/L. These values are slightly lower than the average calcium (36 mg/L) and magnesium (10 mg/L) concentrations of the waters discharged by Sanlando Spring, Palm Spring, and Starbuck Spring. Below the major anthropogenic point-source discharges, calcium and magnesium concentrations in the upper Little Wekiva River averaged about 26 mg/L and 6 mg/L, respectively, during 1985 and 1986 (Tables 18 and 19). Downstream of the springs, average calcium and magnesium concentrations were further increased to about 31 mg/L and 8.5 mg/L, respectively. Calcium and magnesium concentrations were not significantly different between Station 14 and Station 25 during our study years, but calcium and magnesium concentrations were reduced during periods of increased flow along the entire length of the stream.

Concentrations of sodium, potassium, chloride, and sulfate are typically enriched in treated wastewater. Sodium and potassium concentrations in the effluents of the Altamonte Springs Regional Wastewater Treatment Plant and the Weathersfield Sewage Treatment Plant averaged 47-55 mg/L (Table 20) and 8.9-11 mg/L (Table 21), respectively, during 1985 and 1986. Chloride concentrations in the effluents averaged between 42 and 50 mg/L (Table 22). Sulfate concentrations in the effluent from the Altamonte Springs Regional Treatment Plant averaged 57 mg/L in 1985 and 40 mg/L in 1986 (Table 23). Sulfate concentrations in the water leaving the Weathersfield Sewage Treatment Plant, however, were significantly lower, averaging about 28 mg/L (Table

Table 20. Mean, minimum, and maximum sodium concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Sodium (mg/L)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	11 (± 1)	7.8	13
	1986	9.7 (± 2)	8.0	11
2	1985	11 (± 1)	7.6	13
3	1985	12 (± 1)	7.6	14
	1986	10 (± 2)	7.8	12
Altamonte Spring STP	1985	55 (± 3)	48	63
	1986	47 (± 6)	41	55
6	1985	39 (± 8)	16	52
	1986	24 (± 10)	13	34
Weathersfield STP	1985	48 (± 5)	30	59
	1986	51 (± 2)	49	54
8	1985	41 (± 9)	17	53
Hi-Acres	1985	4.8 (± 0.1)	4.5	5.4
	1986	4.9 (± 0.5)	4.6	5.1
10	1985	28 (± 5)	14	36
	1986	22 (± 9)	13	34
11	1985	25 (± 6)	11	38
12	1985	23 (± 4)	13	35
	1986	18 (± 8)	12	27
Sanlando Spring (13.1)	1985	7.5 (± 0.1)	7.2	7.7
	1986	7.5 (± 0.3)	7.1	7.8
(13.3)	1985	7.6 (± 0.1)	7.3	8.3
	1986	7.7 (± 0.4)	7.2	8.0
Palm Spring	1985	7.3 (± 0.1)	7.1	7.5
	1986	7.3 (± 0.2)	7.1	7.6
Starbuck Spring	1985	9.8 (± 0.3)	9.4	11
	1986	9.9 (± 0.2)	9.7	10
14	1985	14 (± 1)	10	17

Table 20. Continued

Station	Year	Sodium (mg/L) Mean	Minimum	Maximum
15	1985	13 (± 1)	10	16
16	1985	13 (± 1)	11	16
	1986	12 (± 2)	11	14
17	1985	14 (± 1)	12	17
	1986	13 (± 2)	10	15
18	1985	14 (± 1)	12	17
19	1985	15 (± 1)	12	17
20	1985	15 (± 1)	12	17
21	1985	15 (± 1)	13	16
	1986	14 (± 2)	11	15
22	1985	15 (± 1)	13	17
23	1985	15 (± 1)	14	17
24	1985	15 (± 1)	14	17
25	1985	15 (± 1)	14	17
	1986	14 (± 1)	13	16

Table 21. Mean, minimum, maximum potassium concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Potassium (mg/L) Mean	Minimum	Maximum
Lotus Lake	1985	3.6 (± 0.4)	2.6	4.2
	1986	3.6 (± 0.7)	3.0	4.1
2	1985	3.7 (± 0.4)	2.6	4.4
3	1985	4.2 (± 0.6)	2.7	5.8
	1986	3.8 (± 0.6)	3.0	4.4
Altamonte	1985	9.3 (± 0.4)	8.1	10
Spring STP	1986	8.9 (± 0.8)	7.9	9.8
6	1985	7.3 (± 1.2)	3.9	9.6
	1986	5.8 (± 1.7)	3.8	7.2
Weathersfield	1985	9.6 (± 1.1)	5.5	12
STP	1986	11 (± 1)	10	11
8	1985	7.5 (± 1.4)	4.0	9.6
Hi-Acres	1985	0.9 (± 0.1)	0.8	1.5
	1986	0.8 (± 0.2)	0.7	0.9
10	1985	5.3 (± 0.8)	3.7	7.5
	1986	5.2 (± 1.4)	3.9	7.2
11	1985	4.8 (± 0.7)	3.1	6.0
12	1985	4.5 (± 0.5)	3.4	5.8
	1986	4.6 (± 1.2)	3.6	5.9
Sanlando (13.1)	1985	1.6 (± 0.1)	1.5	1.7
Spring	1986	1.6 (± 0.1)	1.5	1.7
(13.3)	1985	1.6 (± 0.1)	1.4	1.9
	1986	1.7 (± 0.2)	1.6	2.0
Palm Spring	1985	1.0 (± 0.2)	0.1	1.1
	1986	1.1 (± 0.1)	1.1	1.2
Starbuck Spring	1985	1.2 (± 0.1)	1.2	1.3
	1986	1.3 (± 0.1)	1.3	1.4
14	1985	2.6 (± 0.1)	2.2	3.0

Table 21. Continued

Station	Year	Potassium (mg/L) Mean	Minimum	Maximum
15	1985	2.3 (± 0.1)	2.0	2.4
16	1985	2.3 (± 0.1)	2.0	2.6
	1986	2.5 (± 0.4)	2.2	2.9
17	1985	2.5 (± 0.1)	2.1	2.8
	1986	2.7 (± 0.3)	2.4	3.0
18	1985	2.5 (± 0.1)	2.2	2.8
19	1985	2.6 (± 0.1)	2.4	2.9
20	1985	2.7 (± 0.2)	2.4	2.9
21	1985	2.7 (± 0.2)	2.4	2.9
	1986	2.7 (± 0.2)	2.5	2.8
22	1985	2.6 (± 0.2)	2.4	2.9
23	1985	2.6 (± 0.2)	2.4	2.8
24	1985	2.6 (± 0.2)	2.4	2.8
25	1985	2.6 (± 0.2)	2.4	2.9
	1986	2.8 (± 0.3)	2.4	3.1

Table 22. Mean, minimum, and maximum chlroide concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Chloride (mg/L)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	18 (± 3)	13	23
	1986	17 (± 4)	13	19
2	1985	18 (± 2)	12	23
3	1985	19 (± 2)	12	23
	1986	17 (± 3)	13	19
Altamonte Spring STP	1985	47 (± 2)	42	52
	1986	42 (± 5)	38	49
6	1985	36 (± 6)	18	45
	1986	27 (± 9)	17	36
Weathersfield STP	1985	46 (± 5)	28	59
	1986	50 (± 3)	46	52
8	1985	36 (± 6)	19	45
Hi-Acres	1985	8.3 (± 1)	7.0	12
	1986	8.0 (± 2)	7.0	8.8
10	1985	26 (± 4)	18	32
	1986	24 (± 7)	16	32
11	1985	25 (± 4)	14	32
12	1985	23 (± 3)	16	31
	1986	21 (± 5)	16	26
Sanlando (13.1) Spring	1985	12 (± 0.5)	11	13
	1986	12 (± 0)	12	12
(13.3)	1985	13 (± 0.4)	12	13
	1986	12 (± 1)	12	13
Palm Spring	1985	12 (± 0.5)	11	14
	1986	12 (± 0)	12	12
Starbuck Spring	1985	16 (± 0.4)	15	17
	1986	16 (± 0)	16	16
14	1985	17 (± 1)	14	20

Table 22. Continued

Station	Year	Chloride (mg/L)		
		Mean	Minimum	Maximum
15	1985	17 (± 1)	15	19
16	1985	17 (± 1)	14	18
	1986	17 (± 1)	16	18
17	1985	18 (± 2)	16	20
	1986	17 (± 2)	15	18
18	1985	18 (± 1)	16	20
19	1985	19 (± 1)	16	20
20	1985	19 (± 1)	16	20
21	1985	19 (± 1)	17	20
	1986	19 (± 3)	17	23
22	1985	19 (± 1)	17	20
23	1985	20 (± 1)	17	23
24	1985	20 (± 1)	18	22
25	1985	20 (± 1)	18	23
	1986	20 (± 2)	19	24

Table 23. Mean, minimum sulfate concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Sulfate (mg/L) Mean	Minimum	Maximum
Lotus Lake	1985	14 (± 2)	11	18
	1986	14 (± 2)	12	15
2	1985	15 (± 3)	11	28
3	1985	16 (± 2)	11	23
	1986	14 (± 2)	12	15
Altamonte Spring STP	1985	57 (± 11)	35	90
	1986	40 (± 2)	36	45
6	1985	41 (± 12)	15	71
	1986	23 (± 7)	15	29
Weathersfield STP	1985	27 (± 4)	18	40
	1986	29 (± 4)	25	33
8	1985	43 (± 12)	15	66
Hi-Acres	1985	5.3 (± 0.6)	3.7	7.0
	1986	3.8 (± 0.7)	3.4	4.2
10	1985	26 (± 6)	14	40
	1986	20 (± 7)	16	30
11	1985	24 (± 6)	12	41
12	1985	22 (± 5)	12	41
	1986	17 (± 6)	13	25
Sanlando Spring (13.1)	1985	9.6 (± 0.6)	8.5	12
	1986	9.6 (± 1.5)	8.4	11
(13.3)	1985	9.4 (± 0.5)	8.2	10
	1986	9.9 (± 1.2)	8.8	11
Palm Spring	1985	17 (± 0.6)	16	19
	1986	19 (± 2)	17	20
Starbuck Spring	1985	16 (± 1)	13	19
	1986	18 (± 2)	16	20
14	1985	18 (± 2)	13	23

Table 23. Continued

Station	Year	Sulfate (mg/L) Mean	Minimum	Maximum
15	1985	16 (± 2)	12	22
16	1985	17 (± 2)	13	23
	1986	17 (± 3)	16	22
17	1985	18 (± 2)	14	25
	1986	17 (± 2)	14	20
18	1985	19 (± 2)	14	24
19	1985	19 (± 2)	14	25
20	1985	19 (± 2)	14	24
21	1985	19 (± 2)	17	23
	1986	19 (± 3)	16	23
22	1985	19 (± 2)	15	25
23	1985	20 (± 2)	16	26
24	1985	21 (± 2)	16	28
25	1985	20 (± 2)	17	30
	1986	22 (± 4)	17	24

23). The waters of the upper Little Wekiva River above the Altamonte Springs discharge had an average sodium concentration of 11 mg/L, an average potassium concentration of 3.7 mg/L, an average chloride concentration of 18 mg/L, and an average sulfate concentration of 15 mg/L. Following the addition of the treated wastewaters, average concentrations of these ions in the upper Little Wekiva River increased by over 100%, but concentrations were significantly reduced by additions of water from the Hi-Acres Citrus processing plant (Tables 20, 21, 22, 23). Sodium concentrations in the cooling effluent averaged 4.9 mg/L (Table 20) during 1985 and 1986, and potassium concentrations averaged 0.9 mg/L (Table 21). Chloride concentrations averaged 8.1 mg/L (Table 22), and sulfate concentrations averaged < 5.5 mg/L (Table 23).

Sodium and potassium concentrations at Station 12 averaged 23 mg/L and 4.5 mg/L, respectively, in 1985 and 18 mg/L and 4.6 mg/L, respectively, in 1986. Sodium and potassium concentrations in the waters leaving Sanlando Spring, Palm Spring, and Starbuck Spring averaged < 10 mg-Na/L and < 2 mg-K/L (Tables 20 and 21). Sodium concentrations downstream of the springs averaged between 13 and 15 mg/L, and potassium concentrations averaged between 2.3 and 2.8 mg/L. Chloride concentrations averaged 12 mg/L in Sanlando Spring and Palm Spring but 16 mg/L in Starbuck Spring. Chloride concentrations between Station 14 and Station 25 averaged 17-20 mg/L (Table 22). Sulfate concentrations in Sanlando Spring averaged 9.6 mg/L during 1985 and 1986, but sulfate concentrations in Palm Spring and Starbuck Spring averaged 18 mg/L and 17 mg/L, respectively. Downstream of the springs, sulfate concentrations averaged between 16 and 22 mg/L, which were similar to the average concentrations measured at Station 12. During 1985, the Altamonte Springs Regional Wastewater Treatment Plant contributed about 29% of the sodium, 28% of the potassium, 18% of the chloride, and 22% of the sulfate exported from the Little Wekiva River. Higher flows during 1986 reduced these values to 17%, 18%, 12%, and 9%, respectively. Since late 1986, discharges from the Hi-Acres Citrus processing plant have ceased. Concentrations of the major ions should, therefore, increase in the Little Wekiva River below Station 10 in future years.

Suspended Solids

Excessive quantities of suspended solids (turbidity) in a water body significantly affects light penetration into the water. If the concentration of suspended solids becomes high enough, photosynthesis by phytoplankton, attached algae, and submersed aquatic macrophytes will be limited. The abundance (measured as chlorophyll a concentrations) of phytoplankton (Hoyer and Jones 1983) and the maximum depth of colonization of submersed aquatic macrophytes (Canfield et al. 1985) will also be reduced, which can lead to a reduction in the fisheries.

Good or moderate fisheries can be maintained in waters that normally contain 25 to 80 mg/L total suspended solids (European Inland Fisheries Advisory Commission 1964), but the abundance of aquatic vegetation in the water body will be reduced if these high levels are maintained (Hoyer and Jones 1983). Total suspended solids, organic suspended solids, and inorganic suspended solids concentrations in Florida's small streams generally average < 5 mg/L (Tables 24, 25, 26). Higher concentrations, however, can be found in some of the streams of panhandle Florida and in most of the streams of peninsular Florida during major storm events. Total suspended solids in very slow flowing streams such as the St. Johns River can also be increased by the growth of phytoplankton.

Total suspended solids averaged 6.2 mg/L in Lotus Lake during 1985 and 1986 (Table 27). Organic suspended solids constituted 55% of total suspended solids (Table 28), which reflected the large amount of phytoplankton (average chlorophyll *a* concentration > 20 mg/m^3) growing in Lotus Lake. Inorganic suspended solids averaged 2.8 mg/L (Table 29). Downstream of Lotus Lake, the concentrations of total, organic, and inorganic suspended solids were reduced as the upper Little Wekiva River flowed through Trout Lake. Total suspended solids averaged 2.4 mg/L in 1985 and 2.0 mg/L in 1986 at Station 3. Suspended solids concentrations, however, increased downstream of the Altamonte Springs Regional Wastewater Treatment Plant and the Weathersfield Sewage Treatment Plant (Tables 27, 28, 29).

Total suspended solids concentrations in the discharge of the Weathersfield Sewage Treatment Plant averaged 5.6 mg/L during 1985 and 1986 and ranged from a low of 2.4 mg/L to a high of 9.0 mg/L (Table 27). Over 60% of the suspended solids were organic suspended solids (Table 28), reflecting the extensive growths of

Table 24. Mean, minimum, and maximum total suspended solids concentrations measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	Total Suspended Solids (mg/L) Mean	Minimum	Maximum
Little Wekiva	3.3 (± 0.4)	0.8	25
Alexander Springs	2.9 (± 0.7)	0.6	5.6
Ichetucknee River	2.6 (± 2.4)	0.1	14
Alligator Creek	6.1 (± 1.9)	0.8	17
Rock Springs Run	3.7 (± 0.9)	0.6	8.0
Little Econlockhatchee	3.2 (± 0.8)	1.0	7.1
Wacissa River	1.9 (± 0.5)	0.4	4.5
Wekiva River	3.6 (± 0.8)	1.2	9.3
Alafia River	4.2 (± 1.6)	0.5	9.7
Reedy Creek	2.4 (± 1.8)	0.2	11
Pottsburg Creek	11 (± 7)	2.1	36
Mills Creek	4.7 (± 1.7)	1.0	12
St. Marks River	2.2 (± 0.6)	1.2	4.3
Econlockhatchee	2.5 (± 1.2)	0.6	6.4
Hillsborough River	1.8 (± 0.6)	0.6	4.2
Hogtown River	4.3 (± 1.8)	1.8	11
Upper Santa Fe River	3.1 (± 1.5)	0.9	6.8

Table 25. Mean, minimum, and maximum organic suspended solids concentrations measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	Organic Suspended Solids (mg/L)		
	Mean	Minimum	Maximum
Little Wekiva	1.6 (± 0.2)	0.2	13
Alexander Springs	1.8 (± 0.4)	0.5	4.0
Ichetucknee River	0.9 (± 0.7)	0	4.1
Alligator Creek	2.0 (± 0.6)	0.1	4.9
Rock Springs Run	2.4 (± 0.6)	0.4	5.4
Little Econlockhatchee	1.4 (± 0.3)	0.5	2.9
Wacissa River	1.0 (± 0.2)	0.2	1.9
Wekiva River	2.3 (± 0.5)	0.9	6.0
Alafia River	1.6 (± 0.6)	0.1	3.5
Reedy Creek	1.9 (± 1.4)	0.2	8.1
Pottsburg Creek	4.6 (± 3.4)	1.1	13
Mills Creek	1.6 (± 0.2)	0.5	4.3
St. Marks River	0.9 (± 0.3)	0.4	2.0
Econlockhatchee	1.1 (± 0.5)	0.4	2.6
Hillsborough River	1.0 (± 0.3)	0.4	2.2
Hogtown Creek	1.3 (± 0.5)	0.6	3.4
Upper Santa Fe River	1.6 (± 1.0)	0.3	3.8

Table 26. Mean, minimum, and maximum inorganic suspended solids concentrations measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	Inorganic Suspended Solids (mg/L)		
	Mean	Minimum	Maximum
Little Wekiva	1.7 (± 0.2)	0.4	12
Alexander Springs	1.1 (± 0.2)	0.1	2.0
Ichetucknee River	1.7 (± 1.7)	0	10
Alligator Creek	4.1 (± 1.4)	0.7	12
Rock Springs Run	1.2 (± 0.3)	0.2	2.8
Little Econlockhatchee	1.8 (± 0.5)	0.5	4.2
Wacissa River	0.8 (± 0.3)	0.2	2.6
Wekiva River	1.3 (± 0.3)	0.3	3.5
Alafia River	2.7 (± 1.1)	0.4	6.2
Reedy Creek	0.5 (± 0.5)	0	3.5
Pottsburg Creek	6.8 (± 4.0)	0.9	23
Mills Creek	3.0 (± 1.1)	0.5	7.5
St. Marks River	1.3 (± 0.3)	0.6	2.3
Econlockhatchee	1.4 (± 0.7)	0.1	3.8
Hillsborough River	0.8 (± 0.4)	0.2	2.0
Hogtown Creek	3.0 (± 1.3)	1.2	7.9
Upper Santa Fe River	1.5 (± 0.6)	0.6	3.0

Table 27. Mean, minimum, and maximum total suspended solid concentration for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Total Suspended Solids (mg/L)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	6.2 (± 2.3)	3.2	13
	1986	6.2 (± 3.1)	3.7	8.8
2	1985	3.4 (± 1.1)	1.3	5.5
3	1985	2.4 (± 1.6)	0.4	9.0
	1986	2.0 (± 1.0)	1.0	2.8
Altamonte Spring STP	1985	5.8 (± 2.5)	2.6	17
	1986	3.7 (± 3.0)	2.3	8.3
6	1985	4.1 (± 1.3)	2.1	8.8
	1986	3.4 (± 1.7)	2.2	5.3
Weathersfield STP	1985	5.5 (± 1.6)	2.5	9.0
	1986	5.7 (± 3.0)	2.4	8.2
8	1985	4.9 (± 0.9)	2.7	6.5
Hi-Acres	1985	1.1 (± 0.8)	0.3	4.8
	1986	0.8 (± 0.6)	0.4	1.1
10	1985	3.7 (± 1.2)	1.7	8.2
	1986	4.5 (± 1.6)	3.0	6.6
11	1985	8.3 (± 3.1)	4.2	21
12	1985	8.0 (± 3.0)	4.0	21
	1986	11 (± 14)	3.0	33
Sanlando Spring (13.1)	1985	1.2 (± 1.0)	0.2	5.9
	1986	0.5 (± 0.3)	0.2	0.9
(13.3)	1985	0.9 (± 0.4)	0.3	2.0
	1986	0.6 (± 0.4)	0.2	0.9
Palm Spring	1985	0.1 (± 0.1)	0	1.0
	1986	0.2 (± 0.1)	0.1	0.3
Starbuck Spring	1985	1.4 (± 1.0)	0.1	5.0
	1986	1.0 (± 1.1)	0.3	2.2
14	1985	2.3 (± 0.6)	0.8	3.6

Table 27. Continued

Station	Year	Total Suspended Solids (mg/L) Mean	Minimum	Maximum
15	1985	2.3 (± 0.4)	1.3	3.2
16	1985	2.2 (± 0.5)	1.0	3.2
	1986	2.0 (± 0.9)	1.4	2.9
17	1985	2.5 (± 0.4)	1.0	3.6
	1986	2.2 (± 0.8)	1.4	3.2
18	1985	3.4 (± 2.2)	1.2	14
19	1985	2.4 (± 0.4)	1.8	3.2
20	1985	3.2 (± 0.6)	2.3	5.0
21	1985	2.9 (± 0.6)	2.0	5.2
	1986	3.2 (± 2.1)	1.3	6.3
22	1985	4.9 (± 4.5)	2.1	25
23	1985	4.8 (± 2.1)	2.1	11
24	1985	5.8 (± 3.1)	1.9	17
25	1985	3.7 (± 1.1)	2.2	7.0
	1986	3.6 (± 2.5)	1.8	7.0

Table 28. Mean, minimum, and maximum organic suspended solid concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Organic suspended Solids (mg/L) Mean	Minimum	Maximum
Lotus Lake	1985	3.5 (± 1.2)	1.6	5.8
	1986	3.4 (± 2.4)	1.8	5.6
2	1985	2.1 (± 0.7)	1.0	4.1
3	1985	1.4 (± 0.8)	0.3	4.6
	1986	1.2 (± 0.5)	0.7	1.7
Altamonte Spring STP	1985	4.1 (± 2.1)	1.6	14
	1986	2.8 (± 2.6)	1.4	6.7
6	1985	2.5 (± 0.8)	1.4	5.6
	1986	2.0 (± 1.0)	1.3	3.2
Weathersfield STP	1985	3.5 (± 1.1)	1.7	6.6
	1986	4.4 (± 2.3)	1.8	6.8
8	1985	2.6 (± 0.4)	1.6	3.6
Hi-Acres	1985	0.6 (± 0.4)	0.2	2.0
	1986	0.6 (± 0.5)	0.4	0.7
10	1985	2.2 (± 0.9)	1.0	6.0
	1986	2.3 (± 0.8)	1.7	3.2
11	1985	2.7 (± 0.8)	1.2	6.0
12	1985	2.8 (± 0.8)	1.7	6.2
	1986	4.1 (± 4.3)	1.3	11
Sanlando (13.1)	1985	0.6 (± 0.5)	0.1	2.9
	1986	0.3 (± 0.2)	0.1	0.4
(13.3)	1985	0.4 (± 0.2)	0.1	0.9
	1986	0.3 (± 0.2)	0.2	0.6
Palm Spring	1985	0.1 (± 0.02)	0	0.1
	1986	0.1 (± 0.1)	0	0.2
Starbuck Spring	1985	0.6 (± 0.4)	0	2.2
	1986	0.6 (± 0.6)	0.1	1.3

Table 28. Continued

Station	Year	Organic suspended Solids (mg/L) Mean	Minimum	Maximum
14	1985	1.0 (± 0.3)	0.4	1.8
15	1985	1.0 (± 0.2)	0.5	1.3
16	1985	1.0 (± 0.3)	0.2	1.6
	1986	1.1 (± 0.6)	0.5	1.7
17	1985	1.2 (± 0.2)	0.5	1.8
	1986	1.1 (± 0.6)	0.5	2.0
18	1985	1.6 (± 1.0)	0.6	6.0
19	1985	1.1 (± 0.2)	0.8	1.7
20	1985	1.5 (± 0.3)	1.0	2.4
21	1985	1.5 (± 0.3)	1.0	2.6
	1986	1.7 (± 0.9)	0.9	2.9
22	1985	2.5 (± 2.4)	0.9	13
23	1985	2.5 (± 1.1)	1.0	5.8
24	1985	3.0 (± 1.6)	1.0	8.2
25	1985	1.9 (± 0.5)	1.1	3.6
	1986	1.9 (± 1.3)	0.9	3.6

Table 29. Mean, minimum, and maximum inorganic suspended solid concentrations for major point-source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

Station	Year	Inorganic Suspended Solids (mg/L)		
		Mean	Minimum	Maximum
Lotus Lake	1985	2.7 (± 1.4)	1.3	7.4
	1986	2.8 (± 0.5)	1.9	3.7
2	1985	1.2 (± 0.6)	0	3.0
3	1985	1.0 (± 0.8)	0	4.4
	1986	0.8 (± 0.5)	0.3	1.3
Altamonte Springs STP	1985	1.7 (± 0.5)	0.3	2.9
	1986	0.9 (± 0.5)	0.5	1.6
6	1985	1.6 (± 0.5)	0.7	3.2
	1986	1.5 (± 0.7)	0.8	2.2
Weathersfield STP	1985	1.9 (± 0.6)	0.2	3.5
	1986	1.4 (± 0.9)	0.6	2.5
8	1985	2.3 (± 0.7)	1.0	4.2
Hi-Acres	1985	0.5 (± 0.4)	0	2.8
	1986	0.2 (± 0.4)	0	0.4
10	1985	1.5 (± 0.4)	0.7	2.6
	1986	2.2 (± 1.1)	1.2	3.8
11	1985	5.6 (± 2.3)	2.9	15
12	1985	5.1 (± 2.2)	2.3	15
	1986	7.2 (± 9.6)	1.7	22
Sanlando Spring (13.1)	1985	0.6 (± 0.5)	0.1	3.0
	1986	0.2 (± 0.2)	0	0.5
(13.3)	1985	0.5 (± 0.2)	0.2	1.1
	1986	0.3 (± 0.2)	0	0.6
Palm Spring	1985	0.1 (± 0.1)	0	1.0
	1986	0.1 (± 0.1)	0	0.2
Starbuck Spring	1985	0.8 (± 0.6)	0	2.8
	1986	0.4 (± 0.6)	0	1.0

Table 29(Cont.).

Station	Year	Inorganic Suspended Solids (mg/L)		
		Mean	Minimum	Maximum
14	1985	1.4 (± 0.4)	0.4	2.2
15	1985	1.3 (± 0.3)	0.8	1.9
16	1985	1.2 (± 0.3)	0.6	2.1
	1986	0.9 (± 0.4)	0.6	1.2
17	1985	1.3 (± 0.2)	0.5	2.0
	1986	1.1 (± 0.2)	0.9	1.4
18	1985	1.8 (± 1.3)	0.6	7.6
19	1985	1.3 (± 0.2)	1.0	1.8
20	1985	1.6 (± 0.4)	1.1	2.6
21	1985	1.5 (± 0.3)	1.0	2.6
	1986	1.5 (± 1.3)	0.4	3.4
22	1985	2.4 (± 2.2)	0.8	12
23	1985	2.3 (± 1.1)	1.0	5.6
24	1985	2.8 (± 1.6)	0.9	8.4
25	1985	1.8 (± 0.5)	1.0	3.6
	1986	1.6 (± 1.2)	0.9	3.4

phytoplankton (average chlorophyll a > 25 mg/m^3; maximum chlorophyll a 126 mg/m^3) in the final treatment pond. The treatment facility, however, had a minimal effect on suspended solids concentrations in the upper Little Wekiva River because of the small amount of water discharged as compared to the quantity of water discharged from the Altamonte Springs Regional Wastewater Treatment Plant. Total suspended solids concentrations in the discharge of the Altamonte Springs Regional Wastewater Treatment Plant averaged 5.8 mg/L in 1985 and 3.7 mg/L in 1986. Organic suspended solids constituted over 70% of the suspended solids discharged from the plant (Table 28). Total suspended solids in the plant's discharge during 1985 ranged as high as 17 mg/L, and organic suspended solids ranged as high as 14 mg/L. The higher suspended solids values were associated with the discharge of large amounts of floating organic material. The operating records for the treatment plant indicate that suspended solids in the raw wastewater range from 167 to 260 mg/L (HNTB 1985). The Altamonte Springs Regional Wastewater Treatment Plant during 1985 and 1986 was undergoing modifications to expand and upgrade the treatment facility (HNTB 1985). Once all construction is complete, the effluent limitations call for suspended solids concentrations of 5 mg/L (HNTB 1985). Since late 1985, the concentrations of suspended solids in the effluent have fallen and our maximum measured total suspended solids concentration during 1986 was 8.3 mg/L. Further reductions in suspended solids concentrations should occur when the new facilities at the plant are completely operational.

Downstream of the discharge from the Hi-Acres Citrus processing plant, total suspended solids concentrations in the upper Little Wekiva River were generally reduced (Table 27). The Hi-Acres Citrus plant discharged water with a total suspended solids concentration of 1.1 mg/L in 1985 and 0.8 mg/L in 1986. The dilution effect of the cooling water effluent, however, was reduced during periods of high stream flow. Total suspended solids concentrations between Station 10 and Station 12 increased significantly during this study (Tables 27, 28, 29). Total suspended solids at Station 12 averaged 8.0 mg/L in 1985 and 11 mg/L in 1986. Organic suspended solids constituted over 50% of the suspended solids at Station 10, reflecting the importance of the treated wastewaters discharged upstream. Organic suspended solids, however, constituted < 38% of the suspended solids at Station 12. Inorganic suspended solids at Station 12 averaged 5.1 mg/L in 1985 and 7.2 mg/L in 1986. Values > 10 mg/L were measured during periods of higher streamflow. The increase in the quantity of inorganic suspended solids was due primarily to the severe erosion of the stream banks between Stations 10 and 12, runoff from construction sites, and the discharge of stormwater runoff from urbanized areas.

The concentrations of total suspended solids in the Little Wekiva River below Sanlando Spring, Palm Spring, and Starbuck Spring were significantly lower than values measured at Station 12 (Table 27). Total suspended solids in the spring discharges averaged < 1.5 mg/L, but values $\geq$ 5.0 mg/L were measured at Sanlando Spring and Starbuck Spring when the springs were being cleaned of excessive growths of algae and aquatic macrophytes. Between Station 14 and 21, total suspended solids averaged < 4 mg/L (Table 27). Total suspended solids, however, increased significantly at Stations 22 (4.9 mg/L), 23 (4.8 mg/L), and 24 (5.8 mg/L), before declining at Station 25 (3.7 mg/L). Organic suspended solids constituted about 51% of the suspended solids at these stations. Although the cause for the increases in total suspended solids is unknown, it is probably the result of some internal stream process because there are no known point-source discharges in this portion of the Little Wekiva River.

Color

The color of water in an aquatic system is important because it can reduce light penetration (Canfield and Hodgson 1983) and absorb light differentially, which can limit the primary productivity and maximum depth of colonization of aquatic plants. Natural waters exhibiting a yellow to brown color are common throughout Florida (Kaufman 1975). Water color ranges from 0 Pt-Co units in springs to over 500 Pt-Co units in streams draining extensive swamps (Kaufman 1975; Table 30). The waters are generally colored because of organic substances such as humic materials derived from decaying vegetation. Black and Christman (1963) noted a linear relation between total organic matter and the color value of water. Inorganic substances such as iron and manganese can also cause color, and color can be added to waters by wastewater treatment plants, agricultural drainage, and industrial discharges (Kaufman 1975). Increased color in streams

Table 30. Mean, minimum, and maximum color values measured in all study streams. Sampling periods are given in text and values for the Little Wekiva River are for stations 14 to 25. Mean values include no point-source measurements. Numbers in parentheses are the 95% confidence limits.

Stream	Color (Pt-Co units)		
	Mean	Minimum	Maximum
Little Wekiva	30 (± 5)	5	150
Alexander Springs	95 (± 45)	0	300
Ichetucknee River	0 (± 0)	0	0
Alligator Creek	50 (± 15)	5	100
Rock Springs Run	100 (± 55)	0	350
Little Econlockhatchee	110 (± 30)	20	350
Wacissa River	40 (± 20)	5	175
Wekiva River	65 (± 25)	5	300
Alafia River	60 (± 10)	25	90
Reedy Creek	400 (± 95)	100	700
Pottsburg Creek	110 (± 35)	35	225
Mills Creek	275 (± 50)	175	400
St. Marks River	70 (± 35)	10	175
Econlockhatchee	170 (± 50)	25	250
Hillsborough River	95 (± 40)	15	175
Hogtown Creek	70 (± 20)	30	140
Upper Santa Fe River	225 (± 40)	140	300

is observed with increased runoff due to the flush of decayed organic matter from the watershed (Kaufman 1975).

The waters of the upper Little Wekiva River were noticeably brown during 1985 and 1986, and color concentrations between Lotus Lake and Station 3 averaged between 55 and 70 Pt-Co units (Table 31). Values as high as 100 Pt-Co units were observed during periods of high streamflow. Discharges from the Altamonte Springs Regional Wastewater Treatment Plant (range 5-40 Pt-Co units), the Weathersfield Sewage Treatment Plant (range 5-20 Pt-Co units), and the Hi-Acres Citrus processing plant (range 0-15 Pt-Co units) typically had low color concentrations (Table 31). Color concentrations downstream of the discharges at Station 10 were reduced significantly and averaged 30 Pt-Co units during 1985 and 45 Pt-Co units during 1986. Color concentrations did not change significantly between Station 10 and Station 12.

Sanlando Spring, Palm Spring, and Starbuck Spring discharged water with virtually no color during 1985 and 1986 (Table 31). Downstream of the springs, color concentrations in the lower Little Wekiva were further reduced. Color concentrations, however, increased downstream of Station 20 (Table 31). The increases in stream color were much more pronounced during high flows, and color concentrations $\geq$ 100 Pt-Co units were measured from Station 21 to Station 25 at the confluence with the Wekiva River. These increases were due to increased runoff from the surrounding swampy floodplain.

Table 31. Mean, minimum, and maximum color concentrations for major point source discharges and stations along the length of the Little Wekiva River during 1985 and 1986. Numbers in parentheses are the 95% confidence limit.

		Color (Pt-Co units)		
Station	Year	Mean	Minimum	Maximum
Lotus Lake	1985	60 (± 20)	35	100
	1986	70 (± 15)	60	80
2	1985	55 (± 15)	40	100
3	1985	60 (± 10)	40	90
	1986	65 (± 25)	45	100
Altamonte	1985	15 (± 5)	5	40
Springs STP	1986	25 (± 10)	10	35
6	1985	35 (± 15)	15	80
	1986	50 (± 25)	35	80
Weathersfield	1985	15 (± 5)	10	20
STP	1986	15 (± 5)	5	20
8	1985	30 (± 15)	15	80
Hi-Acres	1985	5 (± 5)	0	15
	1986	0 (± 5)	0	5
10	1985	30 (± 15)	15	75
	1986	45 (± 25)	25	80
11	1985	30 (± 15)	10	75
12	1985	30 (± 15)	15	60
	1986	50 (± 25)	25	80
Sanlando (13.1)	1985	0 (± 0)	0	5
Spring	1986	5 (± 5)	0	5
(13.3)	1985	5 (± 5)	0	15
	1986	5 (± 5)	0	15
Palm Spring	1985	0 (± 0)	0	5
	1986	0 (± 0)	0	0
Starbuck Spring	1985	0 (± 0)	0	5
	1986	5 (± 10)	0	15
14	1985	20 (± 5)	5	50

Table 31. Continued

Station	Year	Color (Pt-Co units) Mean	Minimum	Maximum
15	1985	20 (± 10)	10	60
16	1985	20 (± 10)	10	60
	1986	35 (± 20)	15	60
17	1985	20 (± 10)	10	60
	1986	35 (± 25)	15	70
18	1985	20 (± 10)	10	60
19	1985	20 (± 10)	10	60
20	1985	25 (± 15)	10	70
21	1985	30 (± 20)	10	100
	1986	55 (± 45)	20	120
22	1985	30 (± 20)	10	100
23	1985	30 (± 20)	10	120
24	1985	30 (± 20)	10	120
25	1985	35 (± 20)	10	120
	1986	65 (± 60)	20	150